Fortieth Anniversary
Pioneering the Future

SBIR 98-1

NASA
Small Business Innovation Research

1998 Program Solicitation

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April 24, 1998 - July 7, 1998

Contents of NASA SBIR 98-1 Program Solicitation

1998 NASA Small Business Innovation Research Program Solicitation

1.0 Program Description

1.1 Summary

The National Aeronautics and Space Administration (NASA) invites eligible small business concerns to submit Phase I proposals for its 1998 Small Business Innovation Research (SBIR) Program, which is described in this NASA SBIR Program Solicitation. The 1998 solicitation period for Phase I proposals begins April 24, 1998, and ends July 7, 1998. NASA seeks innovative concepts addressing the program needs described in the SBIR Solicitation subtopics and offering commercial application potential.

Subject to the availability of funds, NASA plans to select about 335 proposals no earlier than October 26, 1998 for negotiation of a Phase I fixed-price contract. NASA anticipates that about 40 percent of these Phase projects will be selected for Phase II development.

This Solicitation contains program background information, outlines eligibility requirements for SBIR participants, describes the three SBIR program phases, and provides the information needed for submitting responsive proposals.

1.2 Program Features

1.2.1 Legislative Basis. This Solicitation is issued pursuant to the authority contained in P.L. 97-219, as amended (Small Business Innovation Development Act of 1982) (15 U.S.C. 638). SBIR policy is provided by the Small Business Administration (SBA) through the SBA Policy Directive, January 26, 1993.

1.2.2 Program Purposes. SBIR program purposes established by law include stimulating technological innovation in the private sector, strengthening the role of small business concerns in meeting Federal research and development needs, increasing the commercial application of federally supported research results, and fostering and encouraging participation by socially and economically disadvantaged persons and women-owned small businesses in technological innovation.

1.2.3 Program Funding. Participating agencies conduct SBIR programs by reserving a small percent of their research and development budgets for funding agreements with small business concerns for research or research and development (R/R&D) during the first two phases of the three-phase process described here. Each agency, at its sole discretion, selects the technical topics and subtopics included in its Solicitation and selects its SBIR awards. Follow-on Phase III activities are capitalized by non-SBIR sources of funding for the pursuit of private sector or government sales.

1.2.4 Program Management. The NASA SBIR program is an agency-wide effort that contributes to NASA's mission in planning, directing, and conducting research and development for civilian uses of space and aeronautics. The program also encourages the commercialization of the products of SBIR-sponsored R/R&D. All NASA Field Installations and Headquarters Program Offices participate. The NASA Office of Aeronautics and Space Transportation Technology provides overall policy direction for the SBIR program, while the NASA Goddard Space Flight Center serves as the Program Management Office. NASA Field Installations identify R&D needs, evaluate proposals, make recommendations for selections, and manage the individual projects. The NASA installations that implement the program are the following:

ARC	**Ames Research Center**, Moffett Field, California
DFRC	**Dryden Flight Research Center**, Edwards, California
GSFC	**Goddard Space Flight Center**, Greenbelt, Maryland
HQ	**NASA Headquarters**, Washington, DC
JPL	**Jet Propulsion Laboratory**, Pasadena, California
JSC	**Lyndon B. Johnson Space Center**, Houston, Texas
KSC	**John F. Kennedy Space Center**, Kennedy Space Center, Florida
LaRC	**Langley Research Center**, Hampton, Virginia
LeRC	**Lewis Research Center**, Cleveland, Ohio
MSFC	**George C. Marshall Space Flight Center**, Marshall Space Flight Center, Alabama
SSC	**John C. Stennis Space Center**, Stennis Space Center, Mississippi

1.3 Three-Phase SBIR Program

1.3.1 Phase I. The purpose of Phase I is to determine the scientific and technical merit and feasibility of the proposed innovation and the quality of the performance of the small business concern with a relatively small NASA investment before consideration of further Federal support in Phase II. To be eligible for Phase I selection, a proposal must be based on an innovation having high technical or scientific merit that is responsive to a NASA need described by a subtopic in this Solicitation. Proposals involving high risk are encouraged when the anticipated payoff potential is great. Unsolicited proposals (those not responsive to a subtopic) will be rejected.

Projects are expected to emphasize near-term applicability to NASA. Selection preference will be given to eligible proposals where the innovations are judged to have significant potential for commercial application.

Phase I must concentrate on establishing, through analysis and/or experiment, the scientific or technical merit and feasibility of the proposed innovation and on providing a basis for continued development in Phase II. Proposals must conform to the format described in Section 3 of this Solicitation. Evaluation and selection criteria are described in Section 4.1. NASA is solely responsible for determining the relative merit and value of proposed Phase I projects, selecting proposals for award, and judging the value of Phase I results.

SBIR contractors must have the capability to independently conduct the R/R&D they propose, and Phase I projects should not require the use of NASA facilities or equipment (See Section 5.14). Phase I contractors will have no more than six months in which to complete their Phase I projects, and to submit their Phase I final reports and Phase II proposals.

1.3.2 Phase II. The objective of Phase II is to continue development of those innovations shown to be feasible in Phase I, and that have the highest potential value to NASA and to the U.S. economy. The government is not obligated to fund any specific SBIR Phase II proposal. Participation in NASA SBIR Phase II is limited to those contractors conducting NASA SBIR Phase I projects.

Phase II projects are chosen as a result of competitive evaluations of Phase II proposals. Phase II proposals are more comprehensive than those required for Phase I, and are to be prepared in accordance with instructions provided in the Phase I contract. See Section 4.2.2 of this Solicitation and the Phase I model contract for required contents of Phase II proposals.

The Phase II proposal evaluation and selection criteria are provided in Section 4.2. They include consideration of the results of Phase I, but place greater emphasis non-SBIR funding commitments and evidence of non-government commercial application potential than does Phase I.

Fixed-price contracts are employed in Phase II, with performance periods up to two years.

1.3.3 Phase III. Phase III involves non-SBIR capital to develop commercial applications of a project, either in the Federal government or in the private sector. Phase I, II, and III awards are considered competitive under the Competition in Contracting Act. NASA will give special acquisition preference for Phase III contracts to firms having valid business arrangements that pursue continued development of technology, products, or services developed under NASA SBIR Phase I and II.

1.4 Eligibility To Participate in SBIR

1.4.1 Small Business Concern. Only firms qualifying as small business concerns as defined in Section 2.5 of this Solicitation are eligible to participate in the SBIR program. Socially and economically disadvantaged small business concerns and women-owned small business concerns are particularly encouraged to propose.

1.4.2 Place of Performance. For both Phase I and II, the R/R&D must be performed in the United States (see Section 2.7) .

1.4.3 Principal Investigator. The Principal Investigator is considered key to the success of the effort; therefore a PI's involvement with the project must be substantial. The following requirements are mandatory:

Functions. The functions of the Principal Investigator (PI) are planning and directing the SBIR project, leading it technically and making substantial personal contributions during its implementation, serving as the primary contact with NASA on the project, and ensuring that the work proceeds according to contract agreements. Competent management of PI functions is essential to project success. The Phase I proposal shall describe the nature of the PI's activities and the amount of time that the PI will apply personally on the project. The amount of time the PI proposes to spend on the project must be acceptable to the NASA contracting officer.

Qualifications. The qualifications and capabilities of the proposed PI and the basis for PI selection are to be clearly presented in the proposal. NASA has the sole right to accept or reject a substitute PI based on factors such as education, experience, demonstrated ability and competence, and any other evidence related to the specific assignment.

Co-Principal Investigators. Co-PI's are not acceptable.

Misrepresentation or Substitution. Misrepresentation of PI qualifications and eligibility, or substitution of a PI by the offeror at any time without NASA's advance written approval, will result in rejection of the proposal or termination of the contract.

Primary Employment. The offeror must certify in the proposal that the primary employment of the PI will be with the small business concern at the time of award and during the conduct of the project. Primary employment means the PI will average a minimum of 20 hours per week with the small business concern, and that more than half of the PI's total employed time (including all concurrent employers, consulting, and self-employed time) is spent with the small business. If the PI does not meet these primary employment requirements when the proposal is submitted, the offeror must explain how these requirements will be met if the proposal is selected for contract negotiations that may lead to an award.

Employees of Academic and Non-Profit Organizations. An offeror proposing a PI who is also to be employed concurrently in any capacity by an academic or non-profit organization (The Organization) must include, as part of the proposal, a written release statement by that organization. The PI release statement shall approve concurrent primary employment with the small business concern as defined above, and agree to less than half-time employment by The Organization beginning no later than the time of NASA SBIR contract award to the small business concern and continuing thereafter during contract performance. It must specifically release the employee from all duties, responsibilities, and activities with The Organization required by or implied by employment in that position as much as or more than half-time. Proposals that do not include the required written release statement will be rejected.

1.5 General Information

1.5.1 Electronic Distribution of Solicitation. The 1998 SBIR Program Solicitation is available only via electronic means through the NASA SBIR/STTR home page **(http://sbir.nasa.gov)**, or by requesting an electronic copy on Diskette. When requesting a diskette it is important to specify the platform you are using (IBM or Mac), the word processing application you use, and your complete address. Printed copies of the Solicitation will not be distributed.

Offerors are encouraged to check the SBIR/STTR home page for updates on the program. Any updates or corrections to the Solicitation will be posted there.

1.5.2 Other Means of Contacting NASA SBIR

SBIR Program Support Office:

1) E-Mail. The e-mail address for contacting NASA to request a diskette containing the Solicitation or to request NASA SBIR information is sbirsupport@lan.alliedtech.com.

2) Facsimile Machine. Inquiries and requests may be made by facsimile to 301-918-8154 and must include the name, address, and telephone number of the person making the request and the specific questions or requests.

3) Telephone Information Inquiries. Information about the SBIR program is available by calling 301-918-1980. Office hours are 8:30 a.m. to 5:00 p.m. Eastern Daylight Time (EDT), Monday through Friday.

NASA SBIR Program Manager:

Requests for general information about the NASA SBIR program should be mailed to:

NASA Goddard Space Flight Center
SBIR Program Manager
Paul Mexcur, Code 710.3
Greenbelt, MD 20771-0001

1.5.3 Questions About this Solicitation. To ensure fairness, questions relating to the intent and/or content of research topics in this Solicitation cannot be answered during the Phase I Solicitation period ending July 7, 1998. Only questions requesting clarification of Solicitation instructions and administrative matters will be answered.

1.5.4 Questions Regarding Proposal Status. Except for an acknowledgment of proposal receipt (to be e-mailed within 30 days of the closing date), information about proposal status *will not be available* until final selections are announced (See Section 6.5).

2.0 Definitions: The following definitions apply for purposes of this Solicitation.

2.1 Research or Research and Development (R/R&D)

Any activity that is (1) a systematic, intensive study directed toward greater knowledge or understanding of the subject studied, (2) a systematic study directed specifically toward applying new knowledge to meet a recognized need, or (3) a systematic application of knowledge toward the production of useful materials, devices, systems, or methods, including the design, development, and improvement of prototypes and new processes to meet specific requirements.

2.2 Subcontract

Any agreement, other than one involving an employer-employee relationship, entered into by a Federal government funding agreement awardee calling for supplies or services required solely for the performance of the original funding agreement. See also Sections 3.5.1 Part 9 and 4.2.2 Part 9 of this Solicitation.

2.3 Socially and Economically Disadvantaged Small Business Concern

A socially and economically disadvantaged small business concern is one that is: (1) at least 51% owned by (i) an Indian tribe or a native Hawaiian organization or (ii) one or more socially and economically disadvantaged individuals; and (2) whose management and daily business operations are controlled by one or more socially and economically disadvantaged individuals.

2.4 Socially and Economically Disadvantaged Individual

A member of any of the following groups: African Americans, Hispanic Americans, Native Americans, Asian-Pacific Americans, Subcontinent Asian Americans, other groups designated from time to time by SBA to be socially disadvantaged, or any other individual found to be socially and economically disadvantaged by SBA pursuant to Section 8(a) of the Small Business Act, 15 U.S.C. 637(a).

2.5 Small Business Concern (SBC)

A small business concern is one that, at the time of award of Phase I and Phase II funding agreements, meets the following criteria:

1. Is independently owned and operated, is not dominant in the field of operation in which it is proposing, has its principal place of business located in the United States, and is organized for profit;

2. Is at least 51% owned, or in the case of a publicly owned business, at least 51% of its voting stock is owned by United States citizens or lawfully admitted permanent resident aliens; and

3. Has, including its affiliates, a number of employees not exceeding 500 and meets the other regulatory requirements found in 13 CFR Part 121. Business concerns, other than investment companies licensed, or state development companies qualifying under the Small Business Investment Act of 1958, 15 U.S.C. 661, et seq., are affiliates of one another when, either directly or indirectly, (1) one concern controls or has the power to control the other or (2) a third party controls or has the power to control both. Control can be exercised through common ownership, common management, and contractual relationships. The term "affiliates" is defined in greater detail in 13 CFR 121. The term "number of employees" is also defined in 13 CFR 121.

Small business concerns include sole proprietorships, partnerships, corporations, joint ventures, associations, or cooperatives. Eligible joint ventures are limited to no more than 49% participation by foreign business entities.

2.6 Women-Owned Small Business

A small business concern that is at least 51% owned by a woman or women who also control and operate it. "Control" in this context means exercising the power to make policy decisions. "Operate" in this context means being actively involved in the day-to-day management.

2.7 United States

Means the 50 states, the territories and possessions of the United States, the Commonwealth of Puerto Rico, the Trust Territory of the Pacific Islands, and the District of Columbia.

2.8 Commercialization

The process of developing markets and producing and delivering products or services for sale (whether by the originating party or by others). As used here, commercialization includes both government and non-government markets.

3.0 Proposal Preparation Instructions and Requirements

3.1 Fundamental Considerations

3.1.1 Responsiveness to NASA Need. An SBIR Phase I proposal must present a scientific or technical innovation that addresses a NASA program need as described in a specific subtopic. If the proposed innovation is judged to be not responsive to the subtopic selected by the offeror, the proposal will be classed as non-responsive and rejected without evaluation, in accordance with the SBA Policy Directive and the terms of this Solicitation. SBIR projects should address R/R&D activities requiring significant scientific or technical innovation, either experimental or theoretical. They may or may not involve construction and evaluation of a laboratory prototype and/or analyses.

3.1.2 Phase I Proposal Objective. A Phase I proposal must describe the research effort needed to investigate the feasibility of the proposed scientific or technical innovation . The objective of the Phase I effort must be to determine whether the innovation has sufficient technical merit for proceeding into Phase II R/R&D.

3.1.3 SBIR Project Requirements. The deliverable item at the end of an SBIR Phase I contract shall be a professional-quality report that justifies, validates, and defends the experimental and theoretical work accomplished. Furthermore, this report must demonstrate the basis for judgments about technical merit and feasibility of the innovation presented in the Phase I proposal, and it should connect the Phase I results to Phase II follow-on R/R&D and commercial applications. Delivery of a product or service with the Phase I report may be desirable, but it is not a requirement.

Deliverable items for Phase II contracts shall include products or services in addition to professional-quality reports of further developments or applications of the Phase I results. These deliverables may include prototypes, models, software, or complete products or services; however, the reported results of Phase II must address and provide the basis for validating the innovation and the potential for implementation of commercial applications.

3.1.4 Unacceptable Objectives. Proposed efforts directed toward systems studies; market research; commercial development of existing products or proven concepts; straightforward engineering design for packaging or adaptation to specific applications; studies, laboratory evaluations; and modifications of existing products without innovative changes are examples of projects that are not acceptable for SBIR.

3.1.5 Multiple Proposal Submissions. An offeror may submit any number of **different proposals** to any number of subtopics, but every proposal must be based on a unique innovation, must be limited in scope to just one subtopic, and may be submitted only under that subtopic.

3.1.6 Identical Proposals. Identical proposals and substantially similar proposals based on the same innovation submitted by an offeror to several subtopics are not permitted and will result in all such proposals being rejected without evaluation.

3.2 General Requirements

3.2.1 Page Limitation. A Phase I SBIR proposal shall not exceed a total of 25 standard 8 1/2 X 11 inch (21.6 x 27.9 cm) pages, including cover page, budget, and all enclosures or attachments. Margins should be 1.0 inch (2.5 cm). All material submitted, except required listing of Phase II awards (See Section 3.7), will be included in the page count. Samples, videotapes, slides, or other ancillary items will not be accepted. Offerors are requested not to use the entire 25-page allowance unless necessary**. Proposals exceeding the 25 page limitation will be rejected without consideration.** The program would prefer proposals prepared on both sides of paper, if possible.

3.2.2 Type Size. No type size smaller than 10 point is to be used for text or tables, except as legends on reduced drawings. Proposals prepared with smaller font sizes will be rejected without consideration.

3.2.3 Brevity and Organization. The proposal should be logically organized, direct, and concise.

3.3 Required Format

The required format for a Phase I NASA SBIR proposal is described in the following paragraphs. All required items of information are to be covered fully in the prescribed "Part" order, but the space allocated to each will depend on the project chosen and the offeror's approach. Promotional and non-project-related material should not be included.

Each proposal submitted to the SBIR program must contain the following parts in the order presented:

1. Proposal Cover Sheet (Form 9A), signed in ink, as page 1.
2. Project Summary (Form 9B), as page 2.
3. Technical Proposal (12 parts), including all graphics, and starting at page 3 with a table of contents.
4. Summary Budget (Form 9C), signed in ink.

All of these parts must be presented within the 25-page limitation. **A proposal not addressing all parts will be considered non-responsive to this Solicitation and will be rejected without consideration.** Detailed descriptions of all parts of the proposal follow.

3.4 Proposal Cover and Project Summary

Note: The Proposal Cover Sheet and the Project Summary are public information, and the Government may disclose them. Do not include proprietary information on these forms.

3.4.1 Page 1: Proposal Cover Sheet (Form 9A). A copy of the Proposal Cover Sheet is provided in Section 9.0. Each offeror shall provide complete information for each item and submit the form as required in Section 6.0. The proposal title shall be concise and descriptive of the proposed product. The title should not use acronyms or words like "Development of" or "Study of." The NASA research topic title must not be used as the proposal title.

3.4.2 Page 2: Project Summary (Form 9B). A copy of the Project Summary Sheet is provided in Section 9.0. Each offeror shall provide complete information for each item and submit form 9B as required in Section 6.0. **Without revealing proprietary information and limited to 200 words**, the technical abstract section shall summarize the anticipated results and implications of the approach (both Phases I and II). Potential commercial applications of the technology should also be presented.

3.5 Technical Proposal

3.5.1 The Technical Proposal shall not contain any budget data and **must consist of all twelve parts in the following order.** (Note: Parts that are not applicable must be noted as "Not Applicable.")

Part 1: Table of Contents. Page 3 of the proposal shall begin with a brief table of contents indicating the page numbers of each of the sections of the proposal.

Part 2: Identification and Significance of the Innovation. The first paragraph of Part 2 shall contain (1) a clear and succinct statement of the specific innovation proposed and why it is an innovation, and (2) a brief explanation of how the innovation is relevant and important to meeting the need described in the subtopic. The initial paragraph shall contain no more than 200 words. **NASA will reject proposals that lack this introductory paragraph**. In subsequent paragraphs, Part 2 may also include appropriate background and elaboration to explain the proposed innovation.

Part 3: Phase I Technical Objectives. State the specific objectives of the Phase I R/R&D effort including the technical questions to be answered to determine the feasibility of the proposed innovation.

Part 4: Phase I Work Plan. A detailed description of the Phase I R/R&D plan. The plan should indicate what will be done, where the work will be done, and how the work will be carried out. Phase I R/R&D should address the objectives and questions cited in Part 3, above. The methods planned to achieve each objective or task should be discussed in detail. Schedules, task descriptions and assignments, resource allocations, estimated task hours for each key personnel, and planned accomplishments including project milestones shall be included. Offerors are advised to avoid including proprietary information if at all possible. See Section 5.4.1.

Part 5: Related R/R&D. Describe significant current and/or previous R/R&D that is directly related to the proposal including any conducted by the principal investigator or by the offeror. Describe how it relates to the proposed effort and any planned coordination with outside sources. The offeror must persuade reviewers of his or her awareness of key recent R/R&D conducted by others in the specific subject area. At the offeror's option, this section may include concise bibliographic references in support of the proposal if they are confined to activities directly related to the proposed work.

Part 6: Key Personnel and Bibliography of Directly Related Work. Identify key personnel involved in Phase I activities including their directly related education, experience, and bibliographic information. Where vitae are extensive, summaries that focus on the most relevant experience or publications are desired and may be necessary to meet proposal page and font requirements. Key personnel are the principal investigator and other individuals whose expertise and functions are essential to the success of the project.

This part shall also establish and confirm the eligibility of the principal investigator (see Section 1.4.3), and indicate the extent to which other proposals recently submitted or planned for submission in 1998 and existing projects commit the time of PI concurrently with this proposed activity. Any attempt to circumvent the restriction on PIs working more than half-time for an academic or a non-profit organization by substituting an ineligible PI will result in rejection of the proposal.

Part 7: Relationship with Phase II or other Future R/R&D. State the anticipated results of the proposed R/R&D effort if the project is successful (through Phase I and Phase II). Discuss the significance of the Phase I effort in providing a foundation for the Phase II R/R&D continuation.

Part 8: Company Information and Facilities. This section shall provide adequate information to allow the evaluators to assess the ability of the SBC to carry out the proposed Phase I and projected Phase II and Phase III activities. The offeror should describe the relevant facilities and equipment currently available, and those to be purchased, in order to adequately support the team's proposed activities. **NASA will not fund the acquisition of equipment, instrumentation, or facilities under SBIR Phase I contracts as a direct cost (Section 5.14).** The capability of the offeror to perform the proposed activities and bring a resulting product or service to market must be indicated. Qualifications of the offeror and its principals in marketing related products or services or in raising capital should be presented. If an offeror proposes the use of unique or one-of-a-kind Government facilities, a statement, describing the uniqueness of the facility and it's availability to the offeror at specified times, signed by the appropriate Government Official must be included with the proposal. **Proposals lacking this signed statement will be rejected without evaluation.**

Part 9: Subcontracts and Consultants. Up to one-third of the research and/or analytical work (contract cost less fee) in Phase I may be conducted under subcontract or other business arrangements with others. If the offeror intends such arrangements, they should be described in detail including functions, services, number of hours and labor rates, and extent of effort to be provided. The proposal must include a signed statement by each participating organization or individual that they will be available at the times required for the purposes and extent of effort described in the proposal. For Phase I, a minimum of two-thirds of the work (contract cost less profit) must be performed by the proposing small business concern unless otherwise approved in writing by the contracting officer.

Part 10: Commercial Applications Potential. The commercial potential of the proposed SBIR project is a significant proposal evaluation factor (see Section 4.1.2). Therefore, offerors will discuss in this section the broad commercial applications they contemplate for their project results and their plans to bring the technology to commercial application. Offerors should discuss the following: (a) the specific commercial products or services contemplated and the corresponding target market niche; (b) expected unique competitive advantage of the commercial products or services; (c) nature of the corresponding contemplated commercial venture; (d) importance of the contemplated commercial venture to the offeror's current competitive position and to its strategic planning; and (e) the offeror’s capability and plans to bring the necessary physical, personnel, and financial resources to bear, in a timely way, to result in a viable commercial venture in the reasonable near term subsequent to Phase II (if awarded). Offerors should also describe how they would seek non-SBIR funding needed for Phase II and Phase III activities (see Section 4.2.2, Part 11).

Part 11: Similar Proposals and Awards. A firm may elect to submit proposals for essentially equivalent work under other Federal program solicitations or may have received or expect to receive other Federal awards for essentially equivalent work. In these cases, the offeror will inform NASA of related proposals and awards and must first certify on the Proposal Cover whether the offeror (a) has received Federal government awards for related work, or (b) has submitted currently active proposals for similar work under other Federal government program solicitations or intends to submit proposals for such work to other agencies during 1998. For all such cases, the following information is required:

1. The name and address of the agencies to which proposals have been or will be submitted, or from which awards have been received;
2. Dates of such proposal submissions or awards;
3. Title, number, and date of solicitations under which proposals have been or will be submitted or awards received;
4. The specific applicable research topic for each such proposal submitted or award received;
5. Titles of research projects;
6. Name and title of the principal investigator/project manager for each proposal that has been or will be submitted or award received.

Note: Lack of the required certification on the cover page or failure to declare the existence of related, similar or duplicate awards or proposals will result in rejection of the offer or loss of an award. If no such awards have been received or no such proposals have been submitted or are intended, the offeror shall so state in this part of the proposal.

Part 12: Previous NASA SBIR Awards. Offerors must state the total number of NASA SBIR Phase I and II awards received, and list those received during the last five years, showing contract numbers, the year of award, Phase I or II, the NASA Installations making the award, and project titles. **If no NASA awards have been received, the offeror shall so state.**

3.6 Proposed Budget

3.6.1 Summary Budget. Following the instructions provided with the form, offerors shall complete Form 9C, SBIR Summary Budget, and include it (and any explanation sheets, if needed) as the last page(s) of the proposal. Enough information shall be submitted to explain the offeror's plans for use of the requested funds to enable NASA to determine whether the proposed budget is fair and reasonable.

3.6.2 Property. NASA will not fund facility acquisition under Phase I (See Section 5.14). Proposed costs for materials may be included. "Materials" means property that may be incorporated or attached to a deliverable end item or that may be consumed or expended in performing the contract. It includes assemblies, components, parts, raw materials, and small tools that may be consumed in normal use. Any purchase of equipment or products under an SBIR contract using NASA funds should be American-made to the extent possible.

3.6.3 Travel. Travel during Phase I is not normally essential to prove technical merit and feasibility of the proposed innovation. However, where the offeror deems travel to be essential for these purposes, it is necessary to limit it to one person, one trip to the sponsoring NASA installation. Proposed travel must be described as to purpose and benefits in proving feasibility, and is subject to negotiation and approval by the contracting officer. Trips to conferences are not allowed under the Phase I contract.

3.6.4 Profit. A profit or fee may be included in the proposed budget as noted in Section 5.9.

3.6.5 Cost Sharing. See Section 5.8.

3.7 Addendum for Prior SBIR Phase II Awards

The Small Business Administration requires offerors who have received more than 15 Phase II awards from all agencies since October 1, 1992, to report those awards and their progress toward commercialization. The listing of awards shall be included in a separate "Addendum: Phase II History" that will not be counted against the Phase I 25-page proposal limit. Information for each Phase II contract shall include:

(1) Name of awarding agency
(2) Date of award and date of completion
(3) Funding agreement number and amount
(4) Topic or subtopic name
(5) Project title
(6) Sources, dates and amounts of Federal and/or private sector Phase III follow-on funding agreements
(7) Post-Phase II commercialization activities, including development, marketing, sales, and projections

The Addendum should be concise.

3.8 Check List

The Check List included in this Solicitation is provided to assist the offeror in completing a responsive proposal. It should not be submitted with the proposal.

4.0 Method of Selection and Evaluation Criteria

All Phase I and II proposals will be evaluated and judged on a competitive basis. NASA may elect to fund several or none of the offers to the same subtopic.

4.1 Phase I

Proposals judged to be responsive to this Solicitation will be evaluated on a competitive basis by peer review.

4.1.1 Evaluation Process. Proposals will be first screened for compliance with administrative requirements of the Solicitation. Those that pass are then reviewed to determine whether they respond to the subtopic chosen by the offeror and have described a relevant, specific innovation. Those found to be responsive are evaluated in greater depth at the NASA Installation(s) responsible for the subtopic, using the factors listed under Section 4.1.2. Other NASA Installations may also evaluate and recommend for selection any proposals accepted for evaluation.

Proposals are expected to provide all information needed for complete evaluation, and evaluators are not required to seek additional information. Evaluators are required to use judgment in assessing proposal information, making use of their personal expertise, knowledge and experience. Evaluations will be performed by NASA scientists and engineers and by qualified experts outside of NASA (industry, academia, and other government agencies) as required to determine or verify the merit of every aspect of a proposal.

4.1.2 Phase I Evaluation Criteria. NASA will give primary consideration to the scientific and technical merit and feasibility of the Phase I proposal. The proposal's potential for commercial application will also be a consideration. NASA will uniformly apply the following evaluation factors and procedures to all proposals accepted for review:

> **Factor 1. Scientific and technical merit** and feasibility of the proposed innovation; relevance to the subtopic; benefit to NASA; and the specific objectives and approaches. Innovation and originality are essential considerations.
>
> **Factor 2. Experience and Qualifications of the offeror,** the Principal Investigator and other key personnel, consultants, and subcontractors, if any; and adequacy of instrumentation and facilities to be available for the project.
>
> **Factor 3. Soundness of the proposed work plan,** budget, and schedule for meeting the Phase I objectives of determining the feasibility and merit of the proposed innovation preparatory to proceeding to Phase II.
>
> **Factor 4. Commercial potential** of the proposed innovation in terms of future commercial products and services and the likelihood of the offeror to bring successfully developed technology to commercial application (see Section 2.8).

Technical Merit and Feasibility. The sum of the numerical scores for factors 1, 2, and 3 constitutes the numerical value for the Technical Merit and Feasibility of a proposal. Factor 1 has twice the weight of both Factor 2 and Factor 3.

Commercial Merit. This evaluation will be distinct from the evaluation of technical merit and feasibility and will apply an adjectival rating to the proposals expressing one of the following judgments of Commercial Merit: Excellent, Very Good, Average, Below Average, Poor, or Insufficient Data Provided.

Installation Selection Recommendations. Each NASA Installation will prioritize (rank) its recommendations for selection and submit them to the SBIR Source Selection Official. Recommendations will note the Technical Merit and Feasibility scores and the judgments of Commercial Merit for each proposal and any special considerations. The number of proposals recommended for selection by each Installation may exceed the number finally selected.

4.1.3 Selection. The SBIR Source Selection Official has final selection authority for choosing the specific proposals for contract negotiation. Most selection decisions are aligned with priorities recommended by each Installation. Other factors influencing selection decisions include balance between NASA's strategic enterprises and distribution between critical technology disciplines.

Firms selected for negotiations that may lead to contract awards will be notified by mail. The list of selections will also be made available electronically (see Section 1.5.2) and by NASA Press Release announcement. Each notification letter will identify the Contracting Officer at the NASA Installation responsible for negotiating the Phase I contract.

4.1.4 Contracting. Fixed-price contracts for up to $70,000 and 6-month duration will be issued. Simplified contract documentation is employed. NASA will make the Phase I model contract and other documents available to the public electronically through the Internet (see Section 1.5.2) at the time of selection announcement. Documents that will be available include:

1. The names and contract information for SBIR contracting officers at the NASA installations
2. Certifications and Representations required to support negotiations
3. The model SBIR contract

4. The full text of contract clauses included in the contract by reference

4.2 Phase II

4.2.1 Phase II Proposals. The object of Phase II is to continue the R/R&D effort from Phase I. Only NASA Phase I awardees may compete for NASA Phase II projects. The SBIR Phase I contract will serve as a request for proposal (RFP) for an SBIR Phase II follow-on contract. Phase II proposals are more comprehensive than those required for Phase I. Submission of a Phase II proposal is strictly voluntary and NASA assumes no responsibility for any proposal preparation expenses.

4.2.2 Phase II Proposal Contents. Phase II proposals shall be addressed in the following "Part" order listed. Failure to include any requested information in the proposal may make it non-responsive to the RFP.

Part 1: Cover Page. (Form provided by the NASA Field Center)

Part 2: Project Summary. (Form provided by the NASA Field Center)

Part 3: Table of Contents.

Part 4: Results of the Phase I Project. Briefly describe how Phase I has proven the feasibility of the innovation, provided a rationale for both NASA and commercial applications, and demonstrated the ability of the offeror to conduct R/R&D.

Part 5: Phase II Technical Objectives, Approach, and Work Plan. Define the specific technical objectives of the Phase II research and technical approach to meet these objectives; and provide a work plan defining specific tasks, performance schedules, milestones, and deliverables.

Part 6: Company Information. Describe the capability of the firm to carry out Phase II and Phase III activities including its organization, operations, number of employees, R/R&D capabilities, and experience relevant to the work proposed.

Part 7: Facilities and Equipment. Discuss requirements for and the availability of equipment, instrumentation, and facilities required for Phase II. If an offeror proposes the use of unique or one-of-a-kind Government facilities, a statement, describing the uniqueness of the facility and it's availability to the offeror at specified times, signed by the appropriate Government Official must be included with the proposal. **Proposals lacking this signed statement will be rejected without evaluation.**

Part 8: Key Personnel. Identify the key personnel for the project, confirm their specific availability for Phase II, and discuss their qualifications in terms of education, work experience, and accomplishments that are relevant to the project. For any PI who is an employee of an academic or non-profit organization, provide a release statement as described in Section 1.4.3 of this Solicitation. Proposals that do not include the required written release statement will be rejected.

Part 9: Consultants and Subcontracts. Describe in detail any subcontracting, consultant, or other business arrangements and provide written evidence of their availability for the project. For Phase II, a minimum of one-half of the work (contract cost less profit) must be performed by the proposing small business concern unless approved in writing by the contracting officer.

Part 10: Commercialization and Phase III Plans. Describe: plans for commercialization (Phase III) in terms of each of the following areas:

(1) Product or Service Commercial Feasibility: Provide a description of the (a) contemplated commercial product and/or service, the corresponding commercial venture, and the unique competitive advantage of both; and (b) technical obstacles to commercial applications, as well as plans to address these obstacles.

(2) Market Feasibility and Competition: Describe: (a) the target market niche including the distinction between U.S. Government and other markets; (b) the estimated potential market size in terms of revenues to be realized by the offeror from U.S. Government markets and, separately, from other markets; (c) the competitive environment in terms of present and likely competing similar and alternative technologies, and corresponding competing domestic and foreign entities; and (d) significant developments within the targeted business sector; (e) offeror's ability, if any, to protect relevant technology with patents or rights to exclusive access.

(3) Strategic Relevance to the Offeror: Describe the relevance of the targeted commercial venture to the offeror's: (a) current business segments; (b) relative position with respect to its competitors; and (c) strategic planning for the next 5 years.

(4) Key Management and Technical Personnel and Organizational Structure: Describe: (a) the skills and experience of key management and technical personnel relevant to bringing innovative technology to commercial application, (b) current organizational structure, and (c) plans and timeline for obtaining the balance of all necessary key business development expertise and other staffing not currently in-house.

(5) Production and Operations: Describe: (a) business development progress to date regarding the contemplated commercial venture; (b) obstacles, plans, and associated timetable of key milestones regarding all key business development elements; and (c) sources and components of private physical resources committed to date and plans for obtaining the balance of the necessary physical resources.

(6) Financial Planning: Describe: (a) the amounts and sources of private financial resources expended and committed to date with respect to the technology development project, and separately, with respect to business development of the targeted commercial venture; (b) significant requirements of potential investors, creditors, and insurers of the venture; (c) proforma statement of cash flow with respect to the targeted commercial venture that includes best estimates of at least the following major components and timing thereof: capital investment, revenues, principal and interest payments, depreciation of relevant assets, other operating expenses; and (d) evidence of the offeror's current financial strength (audited or unaudited financial statements may be appended to address this).

Part 11: Capital Commitments Supporting Phases II and III. Describe and document capital commitments from non-SBIR sources or from internal funds for pursuit of Phase II and Phase III. Offerors for Phase II contracts are strongly urged to obtain valid non-SBIR funding support commitments for follow-on Phase III activities and additional support of Phase II from parties other than the proposing firm. Valid funding support commitments must provide that a specific, substantial amount will be made available to the firm to pursue the stated Phase II and/or III objectives. They must indicate the source, date, and conditions or contingencies under which the funds will be made available. Alternatively, self-commitments of the same type and magnitude that are required from outside sources can be considered. If Phase III will be funded internally, offerors should describe their financial position.

Evidence of funding support commitments from outside parties must be provided in writing to the proposing entity and should accompany the Phase II proposal. Letters of commitment should specify available funding commitments, other resources to be provided, and any contingent conditions. Expressions of technical interest by such parties in the Phase II research or of potential future financial support are insufficient and will not be accepted as support commitments by NASA.

Part 12: Related R/R&D. Describe R/R&D related to the proposed work and affirm that the proposed objectives have not already been achieved and that the same development is not presently being pursued elsewhere under contract to the government.

Part 13: Proposal Pricing. Special instructions for pricing the Phase II proposal will be provided in the Phase I contract and may be provided in writing from the contracting officer.

4.2.3 Phase II Evaluation Factors. The evaluation of Phase II proposals that may result from Phase I contracts awarded under this Solicitation will apply the following factors:

Factor 1. Scientific/technical merit and feasibility of the proposed R/R&D, with special emphasis on its innovation, originality, and technical payoff potential if successful, including the degree to which Phase I objectives were met, the feasibility of the innovation, and whether the Phase I results indicate a Phase II project is appropriate.

Factor 2. Future importance and eventual value of the product, process, or technology results to the NASA mission.

Factor 3. Capability of the Small Business Concern. NASA will assess the capability of the concern to conduct Phase II based on: (a) the validity of the project plans for achieving the stated goals; (b) the qualifications and ability of the project team (Principal Investigator, company staff, consultants and subcontractors) relative to the proposed research; and (c) the availability of any required equipment and facilities.

Factor 4. Commercial Potential. Consideration will be given to the following:

(1) Commercial potential of the technology: This includes an assessment of the offeror's ability to demonstrate: (a) a specific, well-defined commercial product or service based on the technology to be developed; (b) a realistic target market niche of sufficient size; (c) that the targeted commercial product or service has strong potential for uniquely meeting a well-defined need within the target market niche; and (d) a commitment of significant private financial, physical, and technical personnel resources.

(2) Demonstrated commercial intent of the offeror: This includes the assessment of the offeror's ability to demonstrate: (a) the importance of the targeted commercial venture to the offeror's current business and strategic planning; (b) a targeted commercial venture that does not rely on continued U.S. Government markets or on other U.S. Government support beyond Government need; and (c) the adequacy of all resource commitments for Phase III development of the technology to a state of readiness for commercial application.

(3) Capability of the offeror to bring successfully developed technology to commercial application: This includes assessment of the offeror's ability to demonstrate: (a) the offeror's past success in bringing SBIR and other innovative technologies to commercial application; (b) well-thought-out business planning; (c) strong likelihood of the offeror's bringing the remaining necessary private financial, physical, personnel and other resources to bear in a timely way to achieve commercial application of the technology in the not too distant term subsequent to Phase II; and (d) the strength of the current and continued financial viability of the offeror.

In applying these commercial criteria, NASA will assess proposal information in terms of credibility, objectivity, reasonableness of key assumptions, independent corroborating evidence, internal consistency, demonstrated awareness of key risk areas and critical business vulnerabilities, and other indicators of sound business analysis and judgment.

4.2.4 Evaluation and Selection. Factors 1, 2, and 3 will be scored numerically. Factors 2 and 3 are of equal importance, while Factor 1 is more important than either 2 or 3. The sum of the scores for Factors 1, 2, and 3 will comprise the Total Technical Merit score for a Phase II proposal. Proposals receiving high numerical scores will be evaluated and rated for their commercial potential using the criteria listed in Factor 4 and by applying the same adjectival ratings as set forth for Phase I proposals (see Section 4.1.2).

Each NASA Installation managing Phase I projects will use these factors to evaluate the Phase II proposals it receives that are responsive to the Phase II RFP. The Installation's SBIR Committee will then rank the evaluated proposals on technical merit and commercial potential, noting other considerations such as NASA priority. Their recommendations and supporting information will then be submitted to the SBIR Source Selection Official. Final selections by the SBIR Source Selection Official will be based on recommendations from all Installations; NASA Headquarters Program Offices assessments of project value to NASA programs and plans; and any other evaluations or assessments (particularly of commercial potential) that may become available to the Source Selection Official.

4.3 Debriefing of Unsuccessful Offerors

After final Phase I and Phase II selection decisions have been announced, an offeror may submit a written request for a debriefing (proposal critique). Telephone requests for debriefings will not be accepted. **Requests must be made within 60 days after notification has been mailed to the offeror** that their proposal was not selected for award. NASA is not obligated to accept late requests.

Debriefings are intended to acquaint the offeror with perceived strengths and weaknesses of the proposal. NASA will provide comments by the evaluators, but debriefings are not opportunities to reopen selection decisions. Debriefings will not disclose the identity of the proposal evaluators nor provide proposal scores, proposal rankings in the competition, or the content of and comparisons with other proposals with which they were in competition.

4.3.1 Phase I. For Phase I proposals, all requests for debriefing must be directed in writing, either by mail or fax, to the SBIR Program Manager (see Section 1.5.2). Written debriefings, which include the comments of the evaluators, will be mailed only to the corporate official designated in the proposal.

4.3.2 Phase II. To obtain debriefings on Phase II proposals, offerors must mail written requests to the Contracting Officer at the NASA Installation to which their Phase II proposal was submitted. Debriefings may be made to either the corporate official or their designee identified in writing to the contracting officer.

5.0 Considerations

5.1 Awards

Both Phase I and Phase II awards are subject to availability of funds. NASA has no obligation to make any specific number of Phase I or Phase II awards based on this Solicitation, and may elect to make several or no awards in any specific technical topic or subtopic.

Resulting from this solicitation, NASA plans to announce the selection of approximately 335 proposals for negotiation of fixed-price Phase I contracts with values not exceeding $70,000. Following contract negotiations and awards, Phase I contractors will have up to six months to carry out their proposed Phase I programs, prepare their final reports, and submit Phase II proposals. NASA intends that all Phase I projects resulting from this solicitation will be placed under contract by early 1999.

NASA anticipates that approximately 40% of the successfully completed Phase I projects resulting from this Solicitation will be selected for Phase II continuations based on the results of Phase I activities and competitive evaluations of Phase II proposals. Phase II funding agreements are fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $600,000.

NASA is not responsible for any monies expended by the offeror before award of any contract resulting from this Solicitation.

5.2 Phase I Final Report

A final report on the Phase I project must be submitted to NASA upon completion of the Phase I research effort. The format, including hard copy and electronic media, and number of copies shall be in accordance with Phase I contract terms. The report shall elaborate the project objectives, work carried out, results obtained, and assessments of technical feasibility. Rights to these data are outlined in Section 5.5 of this Solicitation. Language used in the Phase I report may be used verbatim in the Phase II proposal.

The Phase I final report shall include a single page project summary (on a form provided by NASA for that purpose) identifying the purpose of the research, a brief description of the research carried out, the research findings or results including the degree to which the Phase I objectives were achieved, and whether the results justify Phase II continuation. The potential applications of the project results in Phase III, separately addressing NASA and non-government commercial uses, will also be included. The project summary is to be submitted without restriction for NASA publication. Phase II reporting requirements are detailed in the Phase I contract.

5.3 Payment Schedule for Phase I

Advance payments can be authorized as follows: one-third at the time of award, one-third at project mid-point after award, and the remainder upon acceptance of the final report by NASA. The first two payments will be made 30 days after receipt of valid invoices. The final payment will be made 30 days after acceptance of the final report and other deliverables as required by the contract.

5.4 Treatment and Protection of Proposal Information

In the evaluation and handling of proposals, NASA will make every effort to protect the confidentiality of the proposals and their evaluations. All proposals will be converted into an electronic format (see Section 6.2), placed on a secure NASA only Internet server and access limited to NASA evaluators only.

5.4.1 Proprietary Information. It is NASA policy to use information (data) included in proposals for evaluation purposes only. Public release of information in any proposal submitted will be subject to existing statutory and regulatory requirements.

If proprietary information consisting of a trade secret, proprietary commercial or financial information, or private personal information is provided in an SBIR proposal, NASA will treat it in confidence to the extent permitted by law, provided this information is clearly marked by the offeror with the term "confidential proprietary information" and provided the following legend appears on the title page of the proposal as follows:

> "For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to the offeror as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages ______ of this proposal."

5.4.2 Non-NASA Reviewers. In addition to government personnel, NASA, at its discretion and in accordance with 18-15.413-2 of the NASA FAR Supplement, may utilize qualified individuals from outside the government in the proposal review process. Any decision to obtain outside evaluation shall take into consideration requirements for the avoidance of organizational or personal conflicts of interest and the competitive relationship, if any, between the prospective contractor or subcontractor(s) and the prospective outside evaluator. Any such evaluation will be under agreement with the evaluator that the information (data) contained in the proposal will be used only for evaluation purposes and will not be further disclosed.

5.4.3 Release of Proposal Information. By submission of a proposal, the offeror agrees to permit the government to disclose publicly the information contained on the Proposal Cover and the Project Summary. Other proposal information (data) is considered to be the property of the offeror, and NASA will protect it from public disclosure to the extent permitted by law (see Section 5.5.3). Form B, Project Summary, shall not contain proprietary information.

5.4.4 Final Disposition of Proposals. The government retains ownership of the copies of proposals submitted for evaluation, and they will not be returned to the offeror. Copies of all unsuccessful Phase I proposals will be retained for one year after Phase I selections have been made, after which time non-selected proposals will be destroyed. Successful proposals will be retained in accordance with contract file regulations, normally 6 years and 3 months from project completion.

5.5 Rights in Data Developed Under SBIR Contracts

Rights to data used in, or first produced under, any Phase I or Phase II contract are specified in the clause at FAR 52.227-20, Rights in Data--SBIR Program. The clause provides for rights consistent with the following:

5.5.1. Non-Proprietary Data. Some data of a general nature are to be furnished to NASA without restriction (i.e., with unlimited rights) and may be published by NASA. These data will normally be limited to the project summaries accompanying any periodic progress reports and the final reports required to be submitted (see Section 5.2). The requirement for them will be specifically set forth in any contract resulting from this Solicitation.

5.5.2 Proprietary Data. When data that is required to be delivered under an SBIR contract qualifies as "proprietary," *i.e.*, either data developed at private expense that embody trade secrets or are commercial or financial and confidential or privileged, or computer software developed at private expense that is a trade secret, the Contractor, if the contractor desires to continue protection of such proprietary data, shall not deliver such data to the Government, but instead shall deliver form, fit, and function data.

5.5.3 Non-Disclosure Period. The Government, for a period of 4 years from acceptance of all items to be delivered under an SBIR contract, shall use SBIR data, *i.e.*, data first produced by the Contractor in performance of the contract where such data are not generally known, and which data without obligation as to its confidentiality have not been made available to others by the Contractor or are not already available to the Government, agrees to use these data for Government purposes, and they shall not be disclosed outside the Government (including disclosure for procurement purposes) during the 4 year period without permission of the Contractor, except that such data may be disclosed for use by support Contractors under an obligation of confidentiality. After the 4 year period the Government has a royalty-free license to use, and to authorize others to use on its behalf, these data for Government purposes, but the Government is relieved of all disclosure prohibitions and assumes no liability for unauthorized use by third parties.

5.6 Copyrights

Subject to certain licenses granted by the Contractor to the Government, the Contractor receives copyright to any data first produced by the Contractor in the performance of an SBIR contract.

5.7 Patents

The Contractor may normally elect title to any inventions made in the performance of an SBIR contract. The Government receives a nonexclusive license to practice or have practiced for or on behalf of the Government each such invention throughout the world. To the extent authorized by 35 U.S.C. 205, the Government will not make public any information disclosing such inventions for a reasonable time to allow the Contractor to file a patent application.

5.8 Cost Sharing

Cost sharing is permitted for proposals under this Program Solicitation. However, cost sharing is not required, nor will it be a factor in proposal evaluation except as a consideration for Phase II/III commitments discussed in Section 4.2.2 Part 11. If included, cost sharing should be shown in the summary budget but not included in items labeled "AMOUNT REQUESTED." No profit will be paid under cost-sharing contracts.

5.9 Profit or Fee

Both Phase I and Phase II SBIR contracts should include a reasonable profit except where cost-sharing is proposed. The reasonability of proposed profit is determined by the Contracting Officer during contract negotiations.

5.10 Joint Ventures and Limited Partnerships

Both joint ventures and limited partnerships are permitted, provided the entity created qualifies as a small business concern in accordance with the definition in Section 2.5. A statement of how the workload will be distributed, managed, and charged should be included in the proposal. A copy or comprehensive summary of the joint venture agreement or partnership agreement should be appended to the proposal. This will not count as part of the 25 page limit for the Phase I proposal.

5.11 Similar Proposals and Prior Work

If an award is made pursuant to a proposal submitted under this Program Solicitation, the firm will be required to certify that it has not previously been paid nor is currently being paid for essentially equivalent work by any agency of the Federal government. Failure to acknowledge or report similar or duplicate efforts can lead to the termination of contracts or other actions.

5.12 Contractor Commitments (Phase I)

Upon award of a contract, the contractor will be required to make certain legal commitments through acceptance of numerous clauses in the Phase I contract. The outline that follows illustrates the types of clauses that will be included in the Phase I contract. This is not a complete list of clauses to be included in Phase I contracts, nor does it contain specific wording of these clauses. Copies of complete provisions will be made available prior to contract negotiations.

5.12.1 Standards of Work. Work performed under the contract must conform to high professional standards. Analyses, equipment, and components for use by NASA will require special consideration to satisfy the stringent safety and reliability requirements imposed in aerospace applications.

5.12.2 Inspection. Work performed under the contract is subject to government inspection and evaluation at all reasonable times.

5.12.3 Examination of Records. The Comptroller General (or a duly authorized representative) shall have the right to examine any directly pertinent records of the contractor involving transactions related to the contract.

5.12.4 Default. The government may terminate the contract if the contractor fails to perform the contracted work.

5.12.5 Termination for Convenience. The contract may be terminated by the government at any time if it deems termination to be in its best interest, in which case the contractor will be compensated for work performed and for reasonable termination costs.

5.12.6 Disputes. Any dispute concerning the contract that cannot be resolved by mutual agreement shall be decided by the contracting officer with right of appeal.

5.12.7 Contract Work Hours. The contractor may not require a non-exempt employee to work more than 40 hours in a work week unless the employee is paid for overtime.

5.12.8 Equal Opportunity. The contractor will not discriminate against any employee or applicant for employment because of race, color, religion, age, sex, or national origin.

5.12.9 Affirmative Action for Veterans. The contractor will not discriminate against any employee or applicant for employment because he or she is a disabled veteran or veteran of the Vietnam era.

5.12.10 Affirmative Action for Handicapped. The contractor will not discriminate against any employee or applicant for employment because he or she is physically or mentally handicapped.

5.12.11 Officials Not to Benefit. No member of or delegate to Congress shall benefit from the SBIR contract.

5.12.12 Covenant Against Contingent Fees. No person or agency has been employed to solicit or secure the contract upon an understanding for compensation except bona fide employees or commercial agencies maintained by the contractor for the purpose of securing business.

5.12.13 Gratuities. The contract may be terminated by the government if any gratuities have been offered to any representative of the government to secure the contract.

5.12.14 Patent Infringement. The contractor shall report to NASA each notice or claim of patent infringement based on the performance of the contract.

5.12.15 American-Made Equipment and Products. Equipment or products purchased under an SBIR contract must be American-made whenever possible.

5.13 Additional Information

5.13.1 Precedence of Contract over Solicitation. This Program Solicitation reflects current planning. If there is any inconsistency between the information contained herein and the terms of any resulting SBIR contract, the terms of the contract are controlling.

5.13.2 Evidence of Contractor Responsibility. Before award of an SBIR contract, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to establish responsibility of the offeror. Contractor responsibility includes all resources required for contractor performance, i.e., financial capability, work force, and facilities.

5.13.3 Classified Proposals. NASA will not accept classified proposals.

5.13.4 Unsolicited Proposals. Unsolicited proposals will not be accepted under the SBIR program. Unsolicited proposals include proposals unrelated to a subtopic need.

5.14 Property

In accordance with the Federal Acquisition Regulations (FAR) Part 45, it is NASA's policy not to provide facilities (capital equipment, tooling, test and computer facilities, etc.) for the performance of work under contract. An offeror will furnish their own facilities to perform the proposed work as an indirect cost to the contract. Special tooling required for a project may be allowed as a direct cost.

When an offeror cannot furnish their own facilities to perform required tasks, an offeror may propose to acquire the use of commercially available facilities. Rental or lease costs may be considered as direct costs as part of the total funding for the project. If unique requirements force an offeror to acquire facilities under a NASA contract, they will be purchased as Government furnished equipment (GFE) and titled to the Government.

An offeror may propose the use of unique or one-of-a-kind NASA facilities if essential for the research. Offerors requiring a NASA facility must clearly document and certify that there is no commercially available facility to perform the R&D. It may be difficult, however, to ensure availability, and non-availability may lead to non-selection. Should an offeror propose the use of unique or one-of-a-kind NASA facilities essential for the R/R&D, an agreement with the responsible installation is required and costs for their use will be determined by the installation. These costs may be chargeable in accordance with the government property clause of the contract (See Section 4.1.4). Total contract costs must not exceed the Phase I and Phase II funding limits given in this Solicitation (See Section 5.1).

6.0 Submission of Proposals

6.1 The Submission Process

6.1.1 Submission Requirements

NASA is in the process of converting to a completely electronic process for management of the SBIR and STTR programs. This management approach requires that a proposing firm have Internet access via the World Wide Web, and an E-mail address. The advantages to the firm are:

1. Faster, cheaper, simpler submission of Phase I and Phase II proposals.
2. Faster and better communication among awardee firms, contracting officers, and contracting officer’s technical representatives (COTRs) will expedite Phase I and Phase II contract negotiation, administration and close-out.
3. Faster and better communication between Phase I and Phase II awardee firms and NASA will facilitate success story collection, marketing surveys, intellectual property (i.e. patent) applications, and non-NASA marketing of resultant products.

6.1.2 What Needs to Be Submitted

A proposal submission is comprised of three parts:

1. **Electronic Technical Proposal Submission.** (Section 6.2) The Electronic Technical Proposal must be submitted either with the Internet Submission (Section 6.3) or on electronic media with the Postal Submission (Section 6.4).
2. **Internet Form Submission** of Proposal Cover Sheet (Form 9A), Project Summary Sheet (Form 9B), and Summary Budget Sheet (Form 9C) (Section 6.3) is required
3. **Postal Submission** of the original signed proposal plus three copies. (Section 6.4)

Firms not able to obtain Internet access must request an exemption by calling (301) 286-5661 or (703) 281-1745 by Monday, June 22, 1998. For all other general SBIR inquiries call (301) 918-1980.

6.2 Electronic Technical Proposal Preparation

By **technical proposal**, we mean the **part of the submission as described in Section 3.5.**

Word Processor. NASA converts all electronic technical proposal files to PDF format for evaluation purposes. Therefore, NASA requests that technical proposals be submitted in PDF format, and encourages companies to do so. Other acceptable formats for PC are AmiPro, ClarisWorks for Windows, MS Works, Text, MS Word, WordPerfect, Postscript, and Adobe Acrobat. Other acceptable formats for Macintosh are ClarisWorks, MS Works, MacWrite Pro, Text, MS Word, WordPerfect, Postscript, and Adobe Acrobat**. If the file is self-extracting, then the offeror is limited to MS Word or WordPerfect formats.** Unix and TeX users please note, due to PDF difficulties with non-standard fonts, please output technical proposal file to DVI format.

Graphics. The offeror is encouraged for reasons of space conservation and simplicity, but not required, to embed graphics within the word processed document. For graphics submitted as separate files, the acceptable file formats (and their respective extensions) are: Bit-Mapped (.bmp), Graphics Interchange Format (.gif), JPEG (.jpg), PC Paintbrush (.pcx), WordPerfect Graphic (.wpg), and Tagged-Image Format (.tif).

Data Compression. Offerors are permitted to submit compressed data files using the Internet or Postal Submission. For PC based submissions, the Pkzip data compression application shall be used. For Macintosh-based submissions, the Stuffit data compression application shall be used.

Limitations. While only the paper copy will be screened for administrative compliance, the various files comprising the electronic version are required to exactly reflect the paper version.

Virus Check. The offeror is responsible for performing a virus check on each submitted technical proposal. As a standard part of entering the proposal into the processing system, NASA will scan each submitted electronic technical proposal for viruses. **The detection, by NASA, of a virus on any submitted electronic technical proposal, may cause rejection of the proposal.**

6.3 Internet Submission

An Electronic Handbook for submitting proposals via the World Wide Web is available on the NASA SBIR/STTR Home Page (**http://sbir.nasa.gov**). The handbook will electronically guide the submitting firm through the various steps for submitting SBIR proposals, and issue secure user identification and passwords for each submission. The electronic handbook also includes: SBIR/STTR overview, schedules, previous awards history, sample proposals, other Federal SBIR/STTR Internet sites, and the 1998 SBIR Solicitation. In addition, the electronic handbook supports secure electronic submission of Forms 9A, 9B and 9C, the technical proposal, award announcements, and debriefings. Communication between NASA and the firm will be via a combination of e-mail and electronic handbooks.

Important: After you have submitted Forms 9A, 9B, and 9C via the Internet, you may use the handbook for printing out the three forms on your own printer. These forms should be used as part of your Postal Submission.

6.4 Postal Submission

Postal Submissions are comprised of:

1. One original signed paper copy of the proposal, including paper copies of all original forms (printed from 6.3 above).
2. Three additional signed paper copies of the entire proposal. Each proposal copy is to be stapled separately.
3. The electronic technical proposal as defined in Section 6.2 (if Internet submission is not utilized). Do not submit Forms 9A, 9B, and 9C on electronic media. These must be submitted via the web site.

6.4.1 Physical Packaging Requirements

Paper Copies of Proposal. Do not use bindings or special covers. Staple the pages of each copy of the proposal in the upper left-hand corner only. Secure packaging is mandatory. NASA cannot process proposals damaged in transit. All items for any proposal must be sent in the same envelope. If more than one proposal is being submitted, each proposal must be in its own envelope, but all proposals may be sent in the same package. Do not send duplicate packages of any proposal as "insurance" that at least one will be received.

Electronic Media for Technical Proposal. If electronic technical proposals are submitted in the Postal Submission, they must be submitted in duplicate (primary and backup) on acceptable electronic media. Acceptable electronic media include 3.5-inch diskettes, Iomega ZIP disks, or CD ROMs in either PC or Macintosh formats. Electronic media can be used to submit multiple electronic technical proposals for multiple submissions as long as: (1) each submission is placed in a separate folder (or directory), and (2) the folder is named using the Internet Submission provided Proposal Submission ID. Electronic media shall be clearly labeled externally with the following information: Primary or Backup, Proposal Title and Number, Offeror Name, Computer Platform and Software used, Compression Program used (if any), and a listing of all files on the media.

6.4.2 Where to Send Proposals

All proposals that are mailed through the U.S. Postal Service first class, registered, or certified mail; proposals sent by express mail or commercial delivery services; or hand-carried proposals **must be** delivered to the following address between 8:30 a.m. and 5:00 p.m. EDT:

Allied Technology Group, Inc.
Mail Stop 120
4200 Forbes Blvd. Suite 106
Lanham, MD 20706-4342

The following telephone number may be used when required for reference by delivery services: (301) 918-1980. **Proposals cannot be received on Saturdays, Sundays, or Federal holidays.**

6.4.3 Deadline for Proposal Receipt

Deadline for receipt of Phase I proposals is 5:00 p.m. EDT on Tuesday, July 7, 1998. Any proposal received after that date and time will be considered late. Since the postmark (or other carrier's date mark) will be the evidence on which the decision is made, offerors must assure themselves that the postmark (or other carrier's date mark) is clear and easily legible; hand cancellation is suggested. Postage meter date stamps are not acceptable**. It is not sufficient for an electronically submitted proposal to be on time, the signed original paper version must be received at NASA by the date and time stated above.** Proposals may not be submitted by facsimile. Late proposals will not be eligible for award and will be rejected without review.

6.5 Acknowledgment of Proposal Receipt

NASA will acknowledge receipt of proposals by email to the address on the proposal cover sheet. If a proposal acknowledgment is not received within 30 days following the closing date of this Solicitation, the offeror should call (301) 918-1980. NASA will not respond to such inquiries made prior to August 7, 1998.

6.6 Withdrawal of Proposals

Proposals may be withdrawn by written notice, fax or telegram received at any time before award. The proposal will remain the property of the U.S. Government and will be destroyed.

7.0 Scientific and Technical Information Sources

7.1 Regional Technology Transfer Centers

NASA's network of Regional Technology Transfer Centers (RTTCs), listed below, provides a variety of business planning and development services to NASA SBIR offerors. However, NASA does not accept responsibility for any services these centers may offer in the preparation of proposals. RTTCs should be contacted directly to determine what services are available and to discuss fees charged since these vary, depending upon the organization and type of service requested. To contact any RTTC, call or check web at http://nctn.hq.nasa.gov.

Northeast:
Center for Technology Commercialization
1400 Computer Drive
Westborough, MA 01581

Southeast:
Southern Technology Applications Center
13709 Progress Boulevard, Box 24
Alachua, FL 32615

Mid-Continent:
Mid-Continent Technology Transfer Center
301 Tarrow, Suite 119
College Station, TX 77843-8000

Mid-Atlantic
Mid-Atlantic Technology Applications Center
3400 Forbes Avenue, 5th Floor
Pittsburgh, PA 15260

Mid-West:
Great Lakes Industrial Technology Center
25000 Great Northern Corporate Center, Suite 260
Cleveland, OH 44070

Far-West:
Far-West Regional Technology Transfer Center
University of Southern California
3716 South Hope Street, Suite 200
Los Angeles, CA 90007-4344

7.2 National Technical Information Services

The **National Technical Information Service**, an agency of the Department of Commerce, is the Federal government's central clearinghouse for publicly funded scientific and technical information. For information about their various services and fees, call or write:

National Technical Information Service
US Department of Commerce
Springfield, VA 22161
Tel: 703-605-6000
Fax: 703-321-8547

On-line access to abstracts of research from all agencies is available through the Federal Research in Progress (FEDRIP) databases accessible through DIALOG, a private information service. For a free copy of the FEDRIP Search Guide, call 703-487-4650 and ask for PR 847.

8.0 Research Topics

NASA has established a framework for making management decisions by separating the Agency's program into externally focused Strategic Enterprises through which we implement our mission and communicate with our external customers (http://www.nasa.gov).

These Enterprises identify, at the most fundamental level, what we do and for whom. They focus us on the ends, not the means, of our endeavors. Each of our Strategic Enterprises is analogous to a strategic business unit employed by private-sector companies to focus on and respond to their customers' needs. Each Strategic Enterprise has a unique set of strategic goals, objectives, and strategies that addresses the requirements of its primary external customers. Because each Enterprise must align its programmatic thrusts with its own customers' needs, each requires its own individual strategy. Research topics and subtopics in this Solicitation are organized by the four Enterprises:

Aeronautics and Space Transportation Technology
Human Exploration and Development of Space
Earth Science
Space Science

In addition, synergy among the Enterprises is captured in a separate section in the Solicitation called ***Crosscutting Technologies***.

There is a total of 28 topics in this Solicitation, each with an introduction followed by a list of subtopics. There is a total of 122 subtopics. These topics and subtopics are found in sections 8.1 through 8.5. Each section has a general introduction and its own table of contents.

8.1 AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY

NASA's Aeronautics and Space Transportation Technology Enterprise pioneers the identification, development, verification, transfer, application, and commercialization of high-payoff aeronautics technologies. It seeks to promote economic growth and security and to enhance U.S. competitiveness through safe, superior, and environmentally compatible U.S. civil and military aircraft and through a safe, efficient national aviation system. In addition, the Enterprise recognizes that the space transportation industry can benefit significantly from the transfer of aviation technologies and flight operations to launch vehicles, the goal being reducing the cost of access to space. The Enterprise will work closely with its aeronautics customers, including U.S. industry, the Department of Defense, and the Federal Aviation Administration, to ensure that its technology products and services add value, are timely, and have been developed to the level where the customer can confidently make decisions regarding the application of those technologies.

http://www.hq.nasa.gov/office/aero/

01 Aviation Safety & Capacity

Aviation Safety represents the effective interaction and integration of five component technologies: 1) zero-tolerance for error in safety critical software and hardware, including software design and testing, power and propulsion development, propulsion control and integration; 2) design and implementation of an effective system to detect and restrict propagation of error and failure in system heath monitoring and data analysis; 3) environmental impact on system performance, including effects of aging, stress, and icing and on information to human monitors/operators; 4) effective and safe design for control of multiple aircraft in the airspace system, through the integration of air and ground based air traffic systems; and 5) integration of human factors in all aspects of the aviation systems operation.

01.01 Human Factors in Aviation Operations
Lead Center: ARC

An important objective in aviation human factors research is to address the interaction of humans with engineered systems. As flight and Air Traffic Control crew roles evolve from those of systems operators to those of systems managers, innovative technologies (devices, techniques, tools, models, and procedures) are needed that pertain to the automation, environment, crew information processing, decision-making, and associated cognitive factors. Innovative and economically attractive approaches are sought to advance technologies supportive of both flight safety and improved efficiency in the following areas:

Reliable Operations
- Individual and crew performance factors.
- Distributed decision-making involving operators, controllers and dispatchers.
- Fatigue and circadian evaluation methods and countermeasures.
- Error reduction in aircraft maintenance.
- Methods of integrating air and ground roles and responsibilities under advanced Air Traffic Management (ATM) concepts.
- Technologies for training on advanced systems and for evaluation of training effectiveness.
- Human performance measurement technology suitable for use in and assessment of operational environments.
- Simulation and modeling tools to assess benefits of new concepts.

Information Management and Display
- Advanced display technologies.
- Integrated displays and procedures.
- Operational concepts and crew system interfaces.

Human-Automation Interaction
- Design methods for human-centered automation.
- Status monitoring systems that inform, advise, or aid the flight crew.
- Flight path planning, re-planning, and communication aids.

01.02 Advanced Concepts in Air-Traffic Management
Lead Center: ARC

Air-Traffic Management (ATM) combines the traditional separation assurance performed by Air-Traffic Control (ATC) and the flight-path management functions concerned with improving system capacity and capability. The challenge for the next generation ATM system is to accommodate growth in air traffic while reducing the aircraft accident rate by a factor of five within 10 years, and by a factor of ten within 20 years. This can only be achieved by the introduction of technical innovations in communication, navigation, and surveillance (CNS) and by the development of decision support tools for controllers, pilots and airline operations. It also requires a new look at the way airspace is managed and automation of some crew functions, thereby intensifying the need for a careful integration of machine and human performance. Innovative and economically attractive approaches are sought to advance technologies in the following areas:

- Decision support tools (DST) to assist pilots, controllers and dispatchers in all parts of the airspace (en route, terminal and surface).
- Integration of DST across different airspace.
- Simulation and modeling tools to assess benefits of new concepts.
- Integration of tools across different airspace.
- Technologies and concepts leading to greater airborne operational independence.
- Flight path planning, re-planning, and communication aids.
- Distributed decision making involving operators and controllers.
- Effect of communication, human performance, and other delays on the stability of the airspace.
- System recovery and safety in the event of failure of sensors and decision support tools.
- Weather modeling and improved trajectory estimation.
- Advanced displays.
- Methods of integrating air and ground roles and responsibilities.
- Human factors and workload concepts relating to safe control/integration of aircraft and other ground vehicles systems.

In addition, at airports the safe ground movement of aircraft, logistics and maintenance vehicles, and emergency vehicles is essential. Under adverse weather conditions (and particularly during emergency conditions) this safety is difficult to ensure and can be compromised. This subtopic solicits proposals for the development of novel concepts and innovative methods to integrate simultaneous movement of the ground vehicle service fleet and the aircraft fleet. The concept must address and provide for the needs of the ground vehicles, as well as aircraft. It must also address both normal and emergency operations. Concept development should include (but not be limited to) consideration of the technical areas listed above for Advanced Concepts in Air-Traffic Management and the following additional areas:

- Implementation of Global Positioning System (GPS) navigation including assessment of system accuracy and environmental effects.
- Data link - The concepts for implementing a compatible data link would be examined. Data transfer rates, error rates, link margins and a traffic analysis should be studied in the process of developing candidate data link hardware concepts.
- System Integration - Development of a recommended system design that insures compatible simultaneous operation of aircraft and ground support vehicles during low visibility conditions.

01.03 Aircraft Ice Protection Systems
Lead Center: LeRC

Improved protection against in flight aircraft icing remains an important objective in aviation safety. NASA seeks proposals that address ice protection, detection, and remote sensing technologies. Proposals are invited that offer improvements through innovative design concepts or integration of existing technologies. Of particular interest are technologies that are compatible with emerging technologies being utilized in new aircraft designs (i.e., sensitive electronic systems, advanced wing design). Onboard systems must be aerodynamically non-intrusive, practical, and must consider weight, power, and size for integration into aircraft. This subtopic solicits innovative concepts that will lead to highly effective and efficient ice protection systems and techniques that are applicable to all classes of aircraft. To receive consideration for funding, all proposals submitted under this subtopic must demonstrate significant advancement over existing technologies. The areas of greatest interest are:

- Non-obtrusive and practical in-flight broad-area reactive ice detection that is sensitive to the full possible spectrum of temperatures, droplet sizes, and liquid water contents.
- Practical, in-flight and/or ground-based, real-time, remote sensing of the super-cooled water droplet and temperature environment. Technology must be capable of quantifying the environment to allow for the prediction of the severity of airframe icing, and to identify potential avoidance and escape routes, and must have practical range and cloud penetration capability.
- Lightweight, low power, and low-cost de-icing and anti-icing systems, including technologies that protect composite structures. A system must have minimal aerodynamic impact in both the normal and icing environments and should be capable of operating automatically or with minimal pilot interaction.
- Onboard systems that can measure and assess changes in the aircraft's overall aerodynamic characteristics in real-time to provide the pilot advanced warning of hazardous performance effects caused by ice accretions.
- Onboard ice management systems that operate, diagnose, and identify the status of the aircraft's ice protection systems. The diagnostic procedures must provide the pilot with a system operation status during flight and hardware maintenance updates as required. These systems should include the dual capacity to transmit meaningful ice sensing information to flight system displays and to ground-based weather service networks.

01.04 High-Integrity Systems and Algorithms
Lead Center: LaRC

The simultaneously increasing complexity of flight systems, and demand for their safe and reliable operation motivate development of techniques for design of high-integrity avionics hardware and software. These include formal, system-level methods for design of hardware and software, providing verifiably safe and reliable execution of the avionics functions. They also include guidance, navigation, and control (GNC) and other vehicle management algorithms that contribute to flight integrity by detecting and identifying adverse conditions such as vehicle faults or erroneous controlled flight, then reconfiguring the vehicle's GNC laws to ameliorate these conditions. In particular, innovative approaches are sought in two main areas: (1) specification, design, and analysis methods for high-integrity digital systems, and (2) theory for synthesis and analysis of GNC algorithms and laws that preserve performance or degrade gracefully as the vehicle experiences breakdown of subsystems.

The system design methods of interest include the following:
- Mathematics-based methods for specification, design, and analysis of digital systems.
- Techniques and tools for integrating formal methods with existing methods, tools, languages, and development standards (such as, RTCA/DO-178B).
- Metrics, measures, and experimental assessment of the effectiveness of particular software development techniques and processes.
- Software safety and risk assessment methods.
- Verified libraries for semi-automatic proof checkers.
- Executable specification languages with complete formal semantics.
- Formally defined specification and programming languages for developing time-critical applications and distributed and parallel software.
- Automatic program generators.
- Error detection and assessment methods, especially automated testing and verification techniques.
- Automated tools and environments to support managing and developing safety-critical systems.
- Innovative approaches to software and systems reuse.

The GNC algorithms of interest include theory and synthesis techniques as follows:

- Rapid reselection or recalculation of the vehicle's flight profile and/or GNC laws to accommodate sudden degradation of or change in its dynamics.
- Efficient and reliable algorithms for fault detection and identification (FDI) with emphasis on FDI of system-level faults which adversely affect the vehicle's dynamics.
- GNC laws that are robust or insensitive to system failures and/or FDI errors.

Approaches that integrate elements from both areas are especially sought.

01.05 Automated On-Line Health Management and Data Analysis
Lead Center: DFRC

Online health monitoring is a critical technology for improving transportation safety in the 21st century. Safe, affordable, and more efficient operation of aerospace vehicles requires advances in online health monitoring of vehicle subsystems and information monitoring from many sources over local/wide area networks. On-line health monitoring is a general concept involving signal processing algorithms designed to support decisions related to safety, maintenance, or operating procedures. The concept of on-line emphasizes algorithms that minimize the time between data acquisition and decision-making. This subtopic seeks solutions for on-line aircraft or spacecraft subsystem health monitoring. Solutions should exploit multiple computers communicating over standard networks where applicable. Solutions can be designed to monitor a specific subsystem or a number of systems simultaneously. Resulting commercial products might be implemented in a distributed decision-making environment such as a virtual flight research center, a disciplinary-specific collaborative laboratory, an on-board diagnostics system, or a maintenance and inspection network of potentially global proportion. Proposers should discuss who the users of resulting products would be, e.g., research/test/development; manufacturing; maintenance depots; flight crew; airports; flight operations or mission control; air traffic management; or airlines. Proposers are encouraged to discuss data acquisition, processing, and presentation components in their proposal. Examples of desired solutions targeted by this subtopic include:

- Real-time autonomous sensor validity monitors.
- Flight control system or flight path diagnostics for predicting loss of control.
- Automated testing and diagnostics of mission-critical avionics.
- Structural fatigue, life cycle, static, or dynamic load monitors.
- Automated nondestructive evaluation for faulty structural components.
- Electrical system monitoring and fire prevention.
- Applications that exploit wireless communication technology to reduce costs.
- Model-reference or model-updating schemes based on measured data that operate autonomously.
- Proactive maintenance schedules for rocket or turbine engines, including engine life cycle monitors.
- Predicting or detecting any equipment malfunction.
- Middleware or software toolkits to lower the cost of developing online health monitoring applications.
- Innovative solutions for harvesting, managing, archival, and retrieval of aerospace vehicle health data.

01.06 Propulsion & Airframe Failure Data & Mitigation
Lead Center: LeRC

NASA is concerned with data, analysis, concepts, and health monitoring that apply to prevention of catastrophic engine and airframe failures, and mitigation of hazardous or accident conditions. All classes and types of aircraft are included. Research is desired which treats the following issues: Aging aircraft (including airframe, engines, and sub-systems) and the potential problems therein. Catastrophic engine failure prevention and light-weight containment of fragments. Occupant protection in a crash, including dynamic analysis, restraints, and structural interaction. Prevention of in-flight and post-crash fires, including detection & suppression concepts and fuel & fuel system modifications to reduce flammability, provide inerting, and/or reduce post-crash spills. Low-cost methods of obtaining related failure and crash data and performing experimental testing. Integration of technologies into existing or new aircraft for the above failure, prevention, and mitigation issues.

02 High Speed Travel

NASA's High Speed Research Program is investigating technology concepts that support economic and environmental requirements of a successful supersonic airliner, moving them out of the laboratory toward practical application. NASA seeks innovations in aerodynamic performance technologies encompassing high lift, transonic, and supersonic cruise conditions, in airframe materials and structures that integrate minimum weight with improved properties and durability and in flight deck systems to improve pilot performance without forward windows. NASA also seeks approaches to resolving environmental issues such as noise reduction and atmospheric effects from engine emissions. Technologies including innovative engine cycles, high temperature engine materials, and propulsion systems that will meet low emissions and low noise requirements also are requested.

02.01 Supersonic Transport Airframe Technologies
Lead Center: LaRC

NASA seeks innovative technology advances that will support development of long distance supersonic commercial transport aircraft. Innovations should provide significant impact on performance, safety and cost, and environmental effects of supersonic transport aircraft. These advances should enable industry to render informed decisions regarding commitment to supersonic transport (SST) production, provide technical solutions for ensuring economic viability and environmental compatibility of future supersonic transport aircraft, and be directed toward validated designs and design methods for application by industry in supersonic aircraft programs. Proposers should show affordable application of the technologies and pathways to commercialization that includes FAA certification if appropriate. Innovations in the following technical areas are sought:

Aerodynamic Performance: Technology concepts that will provide large improvements in aerodynamic performance (supersonic and transonic cruise and low speed, high lift) and aerodynamic control of commercial high-speed air transports. Improvements in supersonic cruise performance are essential to ensure minimum weight supersonic transport designs. Improvements at low speeds in takeoff and landing performance are critical to reduce thrust required and engine takeoff noise. Effective aerodynamic control concepts must provide proper vehicle trim, dynamic response, and flight safety margins with minimum-weight penalty. A major challenge in all of the speed regimes is to develop highly leveraged technologies that integrate well with minimum weight, complexity, and off-design penalties-.

Environmental Issues: Approaches to resolution of environmental issues associated with the design and operation of a supersonic transport are sought. NASA seeks definition of and technology foundations for atmospheric effects from engine emissions, sonic boom, and atmospheric radiation.
- Innovative concepts for jet noise reduction associated with propulsion systems appropriate for the supersonic transport.
- Enhanced understanding of the fundamentals of mixing noise and approaches for modeling and prediction.
- Effects of sonic booms on marine wildlife.

Flight Deck: Innovative and economically attractive technology concepts and systems that will provide significant improvements in the flight deck for commercial high speed air transports:
- Advanced, high-resolution CCD sensors.
- X-band and millimeter wave radar technology (including electronically scanned antennas/systems) for airborne traffic and ground object detection and ground imaging (integrated with existing weather/wind shear radar functions).
- High-resolution, wide field-of-view display technology and concepts.
- Ultra high bandwidth real time video image processing, sensor fusion and image-based object detection processing (especially in the area of machine algorithms for air-to-air collision and near-miss target detection from on-board video cameras).
- Lightweight, high resolution, head-mounted displays.

Materials: Innovative solutions are sought for the following:
- Low-cost fabrication of PMC composite sandwich panels, including metallic surface preparations for bonding the PMC to titanium honeycomb.
- Low-cost fabrication of PMC composite sandwich and skin-stringer panels, including advanced tow placement with *in situ* consolidation, resin transfer molding, and/or resin infusion.
- Lightweight, multi-use insulation that provides thermal, acoustic, and radiation protection for the fuselage and/or thermal protection for the fuel in the wing.
- High-temperature sealant material for the wing fuel tanks.

Structures: Innovative solutions are sought for the following:
- Analytical methods for composite structures to determine any of the following: compressive failure under combined loading, design of damage-tolerant sandwich panels including the effects of crack turning near tear straps, or dynamic fracture mechanics of composite fuselage shells subject to penetration.
- Innovative, lightweight wing/fuselage structural design concepts that use low-cost manufacturing methods.

02.02 Supersonic Transport Propulsion Technologies
Lead Center: LeRC

NASA seeks innovative high-leverage propulsion technologies essential for an economically viable supersonic transport (SST). In particular, high-temperature engine materials are sought that will meet weight, performance, and durability requirements. Also desired are environmentally and economically compatible propulsion components that produce low nitrogen oxide emissions, low noise, high performance, and low specific fuel consumption. Innovative propulsion instrumentation and controls concepts which are enabling for the critical propulsion components or for improved performance and operability of the overall SST propulsion system are also of interest. Specifically, proposals that offer innovations or improvements in the following technical areas are sought:

Enabling Propulsion Materials
- Combustor lining materials with temperature capabilities up to 1200 C with no film cooling.
- Nozzle materials with temperature capabilities up to 1000 C.
- Materials with durability of 18,000 hours.
- Innovative manufacturing process modeling, and design methods for an economically viable SST.

Supersonic Transport Propulsion System Critical Components
- Low emissions (5 gram NO_x/kg fuel), high temperature minimally cooled combustors incorporating, as appropriate, advanced materials for high temperature conditions and 18,000 hour durability.
- Low-noise, lightweight, and highly efficient exhaust nozzles (noise below FAR Stage 36, Stage III and a cruise thrust coefficient of 0.98).
- Low-noise, high-flow per frontal area, efficient fan components.
- Mixed compression inlet system for high-performance (cruise pressure recovery of 0.93), and low approach noise with stable operation.

Alternate Propulsion System Concepts
- Innovative engine cycles which would provide for both environmental compatibility and economic viability for SST's.

Propulsion Instrumentation and Controls
- Innovative instrumentation and sensors that provide information for diagnostics and control of the SST propulsion system and critical components. Optical, thin film and MEMS (Micro Electro-Mechanical

Systems) sensors measuring temperature, pressure, density, velocity and emissions under harsh environments are of special interest.

- Advanced concepts for active control of SST inlet system, robust control of overall propulsion system, integration of inlet/engine/flight control, and active control of low emission combustion system.

03 Subsonic Transport Environmental Compatibility

NASA has very aggressive goals for ensuring the noise and emission environmental compatibility of future aircraft. They are to reduce the perceived noise levels of future aircraft by a factor of two (10 EPNdB) within ten years, and a factor of four (20 EPNdB) within 20 years and to reduce emissions of future aircraft by a factor of three within 10 years and a factor of five within 20 years. These goals are necessary to meet increasingly stringent local, national, and international noise and emission regulations while enhancing operating safety and productivity and increasing aviation system throughput. Noise prediction and reduction technologies are required in the areas of propulsion source noise, nacelle aeroacoustics, airframe noise, and noise minimal flight procedures for jet and propeller airplanes and rotorcraft. In addition, aircraft interior noise reduction technologies are required to improve passenger and crew comfort. Emissions reduction technologies are required for a number of aerosols and particulates including nitrogen oxides, sulfur oxides, carbon dioxide, and water vapor.

03.01 Aircraft Noise Prediction and Reduction
Lead Center: LaRC

Innovative concepts, techniques, and methods are needed in a number of areas of acoustics for developing more efficient and environmentally acceptable airplanes and rotorcraft. Improvements in aircraft noise prediction and control are needed for jet, propeller, rotor, fan, turbomachinery, and airframe noise sources for community residents, aircraft passengers and crew. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid-dynamics techniques for aeroacoustic analysis.
- Reduction concepts and prediction methods for jet noise of subsonic, supersonic, and hypersonic aircraft.
- Concepts for active and passive control of fan, turbomachinery, and jet noise in engine nacelles.
- Reduction concepts and prediction methods for rotorcraft and advanced propeller aerodynamic noise.
- Simulation and prediction of aeroacoustic noise sources including airframe noise and propulsion-airframe integration.
- Computational and analytical structural acoustics techniques for aircraft interior noise prediction.
- Concepts for active and passive interior noise control for aircraft.
- Prediction and control of high-frequency aeroacoustic loads on advanced aircraft structures and the resulting dynamic response.

03.02 Propulsion System Noise Prediction and Reduction
Lead Center: LeRC

NASA’s aggressive subsonic aircraft noise reduction goals will require revolutionary advances in propulsion technologies. Some of the key technologies needed to achieve these goals are fast, highly accurate computational acoustic methods, advanced source identification techniques, and revolutionary propulsion systems for reduced noise and low cost. Advanced computational methods are needed that can both model the relevant flow physics and be used in a design environment. Source identification techniques are needed for both wind tunnel model scale tests and full scale static engine tests to determine the locations of the disturbances that contribute to the overall engine noise levels. It is anticipated that revolutionary noise reduction concepts will be needed to achieve future subsonic noise reduction goals. Therefore, advanced noise reduction concepts need to be identified that provide economical alternatives to conventional propulsion systems. NASA is soliciting proposals in one or more of the following areas for Propulsion System Noise Prediction and Reduction:

- Highly accurate and efficient computational methods for the simulation of turbomachinery noise sources. Methods should have the potential of being 100 (or more) times faster than existing methods while accurately resolving acoustic disturbances.

- Innovative source identification technique for turbomachinery noise.
  - The technique shall be described and demonstrated on a relevant source. A simple source may be used
  - where the solution is known to demonstrate the technique. A clear explanation on how the technique can be applied to turbofan engines should be included. The technique should be capable of identifying sources contributing to dominant engine components, such as fan and jet noise.
    - Fan Noise: The technique shall be capable of separating fan sources such as fan-alone versus fan/stator interaction for both tones and broadband noise. Sufficient resolution is needed to determine the location of the dominant sources on the aerodynamic surfaces.
    - Jet Noise: The technique shall be capable of locating both internal and external mixing noise for dual-flow nozzles found in modern turbofans.

- Innovative turbofan source reduction techniques.
  - Methods shall emphasize noise reduction methods for fan, jet and core components without compromising performance for turbofan engines. A resulting engine system that incorporates one or more of the proposed methods should be capable of reducing perceived noise levels for subsonic engines anywhere from 10 to 20 EPNdB relative to FAR 36, Stage 3 certification levels.

03.03 Subsonic Aircraft Systems Emissions Reduction
Lead Center: LeRC

Current environmental concerns with subsonic aircraft center around global warming an the impact on the earth's climate and, if not addressed, may threaten future market growth. Carbon dioxide (CO2) and oxides of nitrogen (NOx) are the major emittants of concern coming from commercial aircraft engines. CO2 and NOx are both greenhouse gases which impact the warming of the earth's climate. Also, NOx can destroy ozone in the upper atmosphere which protects humans from harmful uv radiation from the sun, and NOx can produce ozone in the lower atmosphere around airports which appears as smog and causes breathing problems in humans. Current state-of-the-art engines and combustors in most subsonic aircraft are fuel efficient and meet the 1996 ICAO nitrogen oxide(NOx) limits. The Kyoto Agreement is applying pressure for additional CO2 reductions, and Europe and the U.S. Environmental Protection Agency are applying pressure for additional NOx reductions at takeoff and possibly cruise conditions. Stringent CO2 and NOx limits could result in emissions' fees or limited access to some countries. Also, recent observations of aircraft exhaust contrails (from both subsonic and supersonic flights) have resulted in growing concern over aerosol, particulate, and sulfur levels in the fuel. In particular, aerosols and particulates from aircraft are suspected of producing high altitude clouds which could adversely affect the earth’s climatology.

NASA has set some very aggressive goals for reducing emissions of future aircraft by a factor of three within ten years and by a factor of five within twenty years. Advanced concepts research for reducing CO2 and analytical and experimental research in characterization (intrusive and non-intrusive) and control (through component design, controls, and/or fuel additives) of gaseous, liquid and particulates of aircraft exhaust emissions is sought. Specific subsonic aircraft operating conditions of interest include the landing-takeoff cycle as well as the in-flight portion of the mission. Areas of particular interest include the following:

- New concepts for reducing carbon dioxide, oxides of nitrogen (NO, NO2, NOy), unburned hydrocarbons; carbon monoxide, particulate, and aerosols emittants (novel propulsion concepts, injector designs to improve fuel mixing, catalysts, additives, etc.);
- New fuels for commercial aircraft which minimize carbon dioxide emissions;
- Innovative active control concepts for emission minimization with an integrated systems focus including emission modeling for control, sensing and actuation requirements, control logic development, and experimental validation are of interest; and

- New instrumentation techniques are needed for the measurement of engine emissions such as NOy, SOx, HOx, atomic oxygen and hydrocarbons in combustion facilities and engines. Size, size distributions, reactivity, and constituents of aerosols and particulates are needed, as are temperature, pressure, density, and velocity measurements. Optical techniques that provide 2D and 3D data; time history measurements; and thin film, fiber optic, and MEMS-based sensors are of interest.

04 Space Transportation

Affordable access to space must be the ultimate goal in order for America to realize the potential for research and commerce in space. NASA envisions the space frontier as a busy crossroads of U.S. led international science, research, commerce, and exploration. Our experience with this vast resource has already yielded new treasures of scientific knowledge, life-enhancing applications for use on Earth and fantastic celestial discoveries. The potential for the future seems almost limitless. Goals include reducing the payload cost to Low Earth Orbit by an order of magnitude, from $10K to $1K per pound, within 10 years and from $1K to $100's per pound by 2020.

04.01 Launch Vehicle Technologies
Lead Center: MSFC

Advanced launch vehicle systems will require high mass fraction, reliable system performance, and extended reusability in order to achieve cost goals. This subtopic emphasizes innovative hardware concepts, subsystems, and design and analysis tools to support development of launch vehicles (not including propulsion systems) while lowering operations cost. Methods, approaches, design and analysis tools, and hardware developed under this subtopic should address technical issues related to tanks, thermal protection systems, structures, guidance, navigation and control (GN&C), supporting discipline analysis, and system integration issues. Specific areas of interest for advanced technologies and innovations include the following:

- Low-cost designs, concepts, and manufacturing processes for tanks and vehicle structures; and innovative approaches and techniques to reduce range costs of small launchers such as Bantam.
- Control and health management of vehicle structural systems by using sensors and effectors that have little influence on the structural system parameters with the exception of the structural damping parameters. Continuous estimation of center of mass and inertial properties. Real-time retuning of control algorithms to reflect known changes in vehicle response or sensor performance, and accurate, continuous estimation of fuel remaining on-board.
- Thermal-protection system concepts, instrumentation analysis tools, and testing techniques for reusable vehicles, cryo-tanks, and vehicle base regions.
- Innovative system level models that support the design and analysis of integration of vehicle subsystems and propulsion systems into the vehicle (such as the ability to assess operability of the systems and to model the impacts of design changes on vehicle cost, operations, vehicle aerodynamics, and controllability).
- Integrated CAD, solid-model, structural, dynamic, thermal, and fluid-flow analysis methods for multi-disciplinary analysis and optimization of launch vehicles, and vehicle subsystems; and improved vehicle analysis tools in the areas of stress, thermal, structural, and fluid dynamics.
- Automated propellant management systems; and technologies and innovative engineering capabilities to produce propulsion storage, feed, pressurization, fill and drain, vent, and support/restraint systems that are robust, lighter, or require less volume.
- Optimal fault detection and redundancy management strategies, on-board autonomous mission planning/abort mode determination, execution software and advanced navigation hardware/software architectures, and adaptive GN&C utilizing data from sensors such as the GPS.
- Analysis and testing techniques for prediction and measurement of damage and stress including life prediction and dynamic response in structures containing ceramic-matrix, metal-matrix composites, or other composite materials; and nondestructive evaluation of structural integrity of vehicle materials and subsystems. Methods for efficient characterization of frequency response functions of large structures, and analysis and testing techniques for passive and active vibration isolation devices for launch vehicles and payloads.

04.02 Advanced/Exotic Propulsion System Technologies
Lead Center: MSFC

Innovative, non-traditional propulsion technologies, devices and systems that could contribute to dramatic reductions in launch costs and in-space transportation time are solicited. Development of such technologies are sought to enable ambitious commercial, robotic, and human exploration missions in the future. Concepts that can be applied to high-payoff commercial applications are of particular interest. Important aspects that should be addressed in the proposal include analyses addressing feasibility and mission suitability, and plans for demonstrating concept feasibility via test/experiment. Areas of interest include the following:

- "Breakthrough" technologies and concepts based on the results of "leading edge" physics research. Of special interest are techniques for manipulation of relativistic phenomena, exploitation of vacuum zero-point fields and/or hyper-fast transportation
- Technology developments in antimatter production, storage, transportation, and utilization for application as a propulsion energy source.
- Propulsion applications of technology innovations in fission or fusion energy production.
- Technology innovations for offboard, beamed power-driven propulsion. Of special interest is research leading to economical launch of small payloads.
- Development of propulsion systems based on solar, laser or magnetically propelled sails or current loops. Of special interest are concepts that could be used for interstellar exploration.
- Components and subsystems for advanced airbreathing/rocket combined cycle engines, deeply cooled turbojets and liquid air cycle engine concepts.
- Advanced high-energy-density propellants and propellant storage/transfer techniques.

04.03 Space Transfer Technologies
Lead Center: MSFC

Advanced, innovative, technologies and system concepts that will achieve reductions in in-space transportation costs are sought. Technologies which offer significant mass or specific impulse improvements over current chemical systems are sought. Other technologies or system concepts that offer improved durability, reduced cost, and reusability over current systems are also of interest. Development of such systems and related technologies are sought to enable ambitious commercial, robotic, and human exploration missions in the future. Concepts that can be applied to high-payoff commercial applications are of particular interest. Proposals should emphasize the potential for reduction in cost, and improvements in performance, reliability, operability or maufacturability over existing systems. Areas of specific interest shall include:

- Chemical propulsion and fluid systems for engines that are used for orbit transfer, in-space transfer and ascent/descent missions are of interest. Other mission applications may include small chemical propulsion for reusable launch vehicles (in-space maneuvering and attitude control systems). Systems that use non-toxic (oxygen based) bipropelllants are of primary interest, but advances in conventional hypergolic propellants are also sought. One type of propellant combination of specific interest for missions to the Moon, Mars, or other planetary bodies include those that can be made from indigenous materials. Figures of merit include lower weight, reduced cost, longer life, improved maintainability, and higher reliability. System/component technologies include: materials compatible with high-temperature, oxidizing and reactive environments; components for fluid isolation, pressure/mass flow regulation, relief quick disconnect, and flow control; techniques for metering, injection, and ignition of fluids in combustion devices; gaseous storage and pressurization systems; non-intrusive component and system diagnostics; systems for liquid-free gas venting, gas free liquid propellant delivery, and mass quantity gauging in reduced gravity environments and systems/components for actuation of aero-surfaces and valves using hydraulic, electro-hydraulic or electromechanical power drives.

- Enhancements to or development of new propulsion systems that use energy sources that do not have to be launched. These may be sources that are available in space such as solar interactions, electromagnetic fields, or atmospheres for capture. Or these sources may be the exchange of momentum between two bodies. Technologies may be in the following areas:
  - Components or system level technologies for solar thermal propulsion. These may include: solar collectors or concentrators, lightweight concentrator support structure, engine/thruster for solar energy conversion, controls and pointing technologies, and system level technologies.
  - Electrodynamic tether propulsion systems or component level technologies. These may include: tether materials or coatings for improved performance and lifetime, designs and analysis for tether behavior and dynamics, testing and characterization techniques for tethers, and system level technologies.
  - Momentum transfer tether propulsion systems or component level technologies. These may include: tether materials or coatings for improved performance and lifetime, designs and analysis for tether behavior and dynamics, testing and characterization techniques for tethers, and system level technologies.
  - Technologies for aerocapture or aeroassisted propulsion systems. These may include materials and thermal protection system technologies, modeling and analysis tools, and system integration issues.

04.04 Lightweight Engine Components
Lead Center: MSFC

Next generation space propulsion systems must address the significant challenge of achieving lower life-cycle cost, increased performance, higher reliability and increased payload or vehicle mass fraction relative to current propulsion systems. Recent emphasis in the performance area has been placed on development of components having increased operational temperature capability, reduced weight, and reusability. Innovative designs and processing methodologies offer potential for cost reduction. NASA, through this subtopic, is seeking research proposals which emphasize justification for selection of material constituents, (e.g. fibers, interface coatings, and fabric architecture), control of processing parameters to ensure successful scale-up and reproducibility, process verification with microscopic analysis (e.g. SEM, XRD, BET, etc.) and macroscopic analysis (e.g. tensile strength, interlaminar shear strength, thermal and physical properties, etc.), application specific verification by testing for permeability, thermal shock, etc., and nondestructive evaluation of components and/or stock material. Phase I & II plans should include delivery of components, test data, and analysis as appropriate. Specific areas of interest include the following:

- Development of lightweight turbomachinery components [e.g. integrally bladed disks (blisks), rotors, stators, housings, seals, etc.] having capability to operate in hot (1000°C) hydrogen rich steam and oxygen rich environments.
- Development of fabrication techniques capable of producing uniform densities in CMC blisks for thicknesses ranging from one to three inches, and diameters up to eighteen inches.
- Innovative technologies providing lower cost, lightweight combustion components (e.g. cooled and uncooled thrust chambers and nozzles, high load capacity nozzle structural components, injector faceplates, minimal erosion throats, etc.) for LOX/H2 and LOX/RP environments.
- Attachment methodology development for joining polymer matrix composites (PMC), CMC and ceramic components to metallic and nonmetallic components (e.g. cooling channel manifolds to nozzles, transmission of high torque loads from metallic rotors to CMC blisks, flanging or connection of ducts to metallics, brazing, diffusion bonding, etc.)
- Ultrahigh temperature (greater than 2000 degrees Celsius) propulsion and plasma confinement development for solar thermal absorbers and nuclear thermal applications.
- Innovative, low cost (with metrics), fabrication methodology development for preceding lightweight component applications.
- Development of functionally gradient materials for preceding applications.
- Innovative, lightweight composite feedlines, ducts, and housings for applications ranging from cryogenic temperatures to 300°C.
- Advancements in the non-destructive evaluation of light weight engine components, including the use of embedded or surface mount smart sensors for real time monitoring of engine components.

- Design of inducers with a suction performance capability of over 85,000 suction specific speed with a inducer tip flow coefficient of over .10.

04.05 Rocket Engine Test Operations
Lead Center: SSC

Proposals are solicited for innovative concepts in the area of test operations. Proposals should support the reduction of overall propulsion test operations costs (recurring costs) and/or increase reliability and performance of propulsion ground test facilities and operations methodologies. Specific areas of interest in this subtopic include the following:

Facility and test article health monitoring technologies:
- Non-intrusive sensors for measuring flow rate, temperature, pressure, rocket engine plume constituents, effluent gas detection, hydrogen leak detection, and hydrogen fires.
- Automated leak detection and/or visualization system for facility and test article propellant systems.
- On-line particulate and quality sampling for facility propellant (liquid oxygen and hydrogen) and support gas systems (helium, hydrogen, oxygen, nitrogen, and missile-grade air).

Improvement in ground-test operation, safety, cost-effectiveness, and reliability:
- Smart system components (control valves, regulators, and relief valves) which provide real-time closed-loop, control, component configuration, automated operation, and component health.
- Cryogenic propellant transfer system operation technologies which include automated propellant transfer, automated propellant-line (liquid hydrogen) purge systems, and automated and/or manual propellant-line quick-disconnect systems.
- Liquid hydrogen boil-off recovery or utilization systems.
- Innovative designs and/or operational techniques for self-pumping, supersonic diffusers for altitude testing of rocket motors.
- Long-life, liquid-oxygen-compatible seal technology.
- Cryogenic storage tank lifetime monitor systems for temperature cycles, stress, acoustics, pressure and shock.

Application of System Science to ground test operations in a resource constrained environment:
- Digital simulations techniques to support decision making processes to address reliability, availability, and return on investment and training of environment for test conductors.
- Techniques to improve high speed data acquisition and high speed video systems for test area data and video transmissions.
- Techniques to reduce required sample size to maintain acceptable levels of confidence in cost data.
- Risk management techniques.

05 General Aviation Revitalization

Numerous factors combine to create opportunities for revitalization of the U.S. general aviation industry and the role of a small aircraft transportation system for business and personal travel in the 21st century. These include rapid growth in air travel (increasing pressure on National Airspace System (NAS) capacity and safety and for affordable NAS operations for the government and users), declining numbers of communities served by scheduled air carriers, increasingly stringent international environmental standards, an aging fleet of small aircraft, and aggressive foreign competition. NASA seeks innovative technologies supporting advances in flight systems, airspace and ground systems infrastructure, integrated design and manufacturing and aircraft configuration design concepts as well as general aviation propulsion technologies.

05.01 General Aviation Transportation System Technologies
Lead Center: LaRC

NASA seeks innovative technologies to support advances for small aircraft transportation systems that substantially increase the demand for retrofit of existing aircraft, new aircraft and airport and airspace utilization. Of specific interest are advanced, affordable, certifiable technologies for human-factors engineered display of flight information for total situational awareness, and simplified integration of flight controls with displays, and propulsion systems. In addition, improvements are desired in cost-effective, user-friendly improvements in weather, traffic, and NAS facilities' information services. NASA also seeks innovations in manufacturing methods and materials.
Specifically, proposals are sought for the following areas:

Aircraft Configuration
- Advanced concepts for roadable aircraft are desired. This category must include a sound business plan for production with a technical plan providing for compatibility with the emerging National Airspace System architecture and a certification plan to meet at least one of the following applicable FARs: Part 103 (Ultra-lite vehicle), Part 21.24 (Primary Category Aircraft), Part 23 (Certified Aircraft) or Part 27 (Rotorcraft), or Part 21.191 Advisory Circular AC No: 20-27 series (Experimental Homebuilt Aircraft).

Flight System Technologies
- **Information Systems and Pilot Vehicle Interface**
  Cost-effective advances in emerging navigation displays, graphical depiction methods, intuitive cockpit display systems, flight controls, voice interface, communications and human factors engineering technologies to aid pilot decision making and to reduce cockpit workload.

- **Certifiable COTS for System Hardware and Software**
  Affordable cockpit systems including sensors, attitude-heading reference systems, terrain and obstacle avoidance systems, and applications for standardized databus system architectures such as firmware, software, design and maintenance tools, and flight information and management products for airplane systems status and flight planning.

Integrated Design and Manufacturing
- Innovative manufacturing methods and materials providing significant advances in the cost, safety, weight, and cabin comfort for general aviation aircraft through materials technology, structural designs and assembly, and crash-worthiness.

All proposals should include supportability plans (support infrastructure, maintenance requirements, operations, and training), certification plans (cite Specific FAR's), compatibility with current and future airspace architecture, and a clear path to commercialization.

05.02 Light Aircraft Engine Design, Systems, and Components
Lead Center: LeRC

NASA seeks proposals that offer dramatic improvements in acquisition and life cycle costs, performance, safety and reliability; environmental compatibility (noise, emissions and fuel), ease of operation and passenger comfort through innovative propulsion concepts and/or integration of innovative propulsion technologies. Emphasis is placed on cost reduction, ease of operation and comfort. Anticipated benefits must be defined using appropriate theoretical and experimental data. Concepts with a clear path to commercialization are highly preferred. Offerors should address commercialization plans and FAA certification issues. Proposals are sought in the following areas:

Propulsion System and Component Technologies
NASA seeks engine concepts (piston, turbine, unconventional) and engine component technologies for light aircraft that will result in substantial improvements over current piston engines. Any improvements in areas such

as performance, safety, and environmental compatibility must be accomplished with affordability as a prime consideration. The offeror must demonstrate acquisition and life cycle costs that are at least comparable to current propulsion system costs. Substantially reduced costs, at least 50% less than current systems, are highly preferred.

Engine Control and Health Monitoring Technology
NASA seeks proposals for low-cost electronic engine control and health monitoring systems which substantially reduce pilot workload, fuel consumption, and engine emissions, and increase time between overhaul (TBO) and safety. Engine diagnostics should focus on pilot notification of engine status and operability, post-flight diagnostic methods, trend analysis and maintenance aides. Much of this technology already exists, but it is too costly and/or too costly to certify for light aircraft. In some cases, cost reductions by orders of magnitude must be achieved. Development of methods for using commercially available high volume hardware and achieving low-cost software production and validation is encouraged. Paths to FAA certification must be described.

06 Next Generation Aircraft Systems Design & Analyses Tools

The Aeronautics Enterprise is engaged in developing the tools, techniques, and technologies to revolutionize the design and development processes of the aerospace industry with the goal to reduce the aircraft development cycle time by one-half. The concept of design spans the evaluation of requirements, consideration of manufacturing, operations support, and other non-traditional domains, effective utilization of ground and flight test results, up to the point of actual manufacture. Information technology, advanced physics-based analytical tools, methods to control the process of design, and innovative test instrumentation are key areas in this effort.

06.01 Advanced Measurement Science and Ground Testing Technology
Lead Center: LaRC

The demand placed on ground and space test programs continually expands, requiring increased global measurement capability, or higher bandwidth and higher spatial resolution single-point measurements. These systems will provide more information per test hour, whether the goal is better CFD code validation for aerodynamics or new models for advanced aerospace systems. Sensors must now be available for both cryogenic and high temperature operation and be able to provide accurate information in a relatively severe vibration environment. Proposed innovations must emphasize near term practical applications, characterize the degree of improvement over existing technologies, and identify commercial applications as much as possible. Proposals for general or investigative studies and systems analysis are not acceptable. Suggested areas of interest and specific technologies for possible development include the following:

- Boundary layer characterization in both conventional and cryogenic wind tunnels.
- Model attitude and deformation measurement system providing 0.005 degree accuracies in a highly dynamic vibratory environment.
- A model force measurement system having an accuracy of the order of 0.01% FS and insensitivity to temperature gradients over a -240 F to +150 F temperature range.
- Micro-Electro-Mechanical Systems (MEMS) for aerodynamic measurements--including flow velocity, pressure, shear stress, and/or acceleration.
- Sensors and systems for optical diagnostics such as global surface pressure measurement for subsonic through hypersonic wind tunnels.
- Innovative molecular sensors for environmental and combustion measurements.
- Onboard data systems and advanced data transmission technologies for wind tunnel model applications.
- Systems for measuring combustion efficiency in SCRAM-jet pulse facilities.

Also, propulsion research instrumentation is needed for fundamental studies of basic phenomena, design code validation, and engine systems tests in aeropropulsion facilities. Of special interest are optical techniques that quantify multiple parameters at multiple spatial points to provide 2D and 3D data in turbomachinery. Time history data is also important. Fluid parameters of interest include temperature, pressure, density, and velocity. Surface parameters of interest include temperature, pressure, stress, strain, deformation, and defect detection. Fiber optic, thin film, and micro electro-mechanical devices are also of interest.

06.02 Unsteady Aerodynamics and Aeroelasticity
Lead Center: LaRC

The technical discipline of aeroelasticity is a critical ingredient necessary in the design process of a flight vehicle for assuring freedom from catastrophic aeroelastic and aeroservoelastic instabilities. This discipline requires a thorough understanding of the complex interactions between a flexible structure and the unsteady aerodynamic forces acting on the structure, and at times, active systems controlling the flight vehicle. Complex unsteady aerodynamic flow phenomena, particularly at transonic mach numbers, are also very important because this is the speed regime most critical to encountering aeroelastic instabilities. In addition, aeroelasticity is presently being exploited as a means for improving the capabilities of high performance aircraft through the use of innovative active control systems using both aerodynamic and smart material concepts. Studies to develop analytical and experimental methodologies for reliably predicting the effects of aeroelasticity and their impact on aircraft performance, flight dynamics, and safety of flight are valuable. Areas of development to be considered include the following:

- Design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Methods to predict aeroelastic phenomena and complex steady and unsteady aerodynamic flow phenomena, especially in the transonic speed range. Aeroelastic phenomena of interest include flutter, buffet, buzz, limit cycle oscillations, and gust response; flow phenomena of interest include viscous effects, vortex flows, separated flows, transonic nonlinearities, and unsteady shock motions.
- Efficient methods to generate mathematical models of wind-tunnel models and flight vehicles for performing vibration, aeroelastic, and aeroservoelastic studies.
- Unique control concepts that employ smart materials embedded in the structure and/or aerodynamic control surfaces for suppressing aeroelastic instabilities or for improving performance.
- Techniques that support simulations, ground testing, wind-tunnel tests, and flight experiments of aeroelastic phenomena.

06.03 Computation Advances for Aerospace Applications

Lead Center: ARC

Improved and enhanced computational techniques are solicited for solving large-scale scientific and engineering problems in many aerospace disciplines. Improvements desired are increased computational speed, graphics, and all aspects of data handling including storage, and long-haul communications. Proposals may address any of the following areas:

Parallel processing: Methods and software for exploiting parallel processing and for easing the task of developing efficient FORTRAN-based programs for parallel processing computers while retaining the efficiency of programs transferred from one architectural design to another; methods for predicting resulting system performance prior to system construction. Architectures of interest include tightly coupled multiple instruction-stream multiple data-stream (MIMD) and loosely coupled MIMD including workstation clusters.

Scientific data management: Software tools and programming libraries that support easy development of new applications that draw from complex, multi-source, multi-disciplinary data, easy definition and management of evolving schema and scientific and engineering data types, data integration and exchange among scientific and engineering disciplines, scientific data management at the "data model" level, management and access of extremely large collections of extremely large data sets.

Graphics: Computer graphics concepts capable of implementation in software and hardware for visualizing complex computational results to bring new understanding to the physical phenomena being modeled, with emphasis on displaying and recording several physical quantities varying over three dimensions and time.

06.04 Rotorcraft/STOVL Aerodynamics and Dynamics
Lead Center: ARC

Many aspects of rotorcraft/STOVL (Short Take-Off and Vertical Landing) aerodynamics and dynamics are not thoroughly understood or adequately predicted to enable efficient and accurate design processes for economically viable, civil aviation aircraft with vertical lift/STOVL capability. NASA requires innovative methods, approaches, and technologies that describe phenomena involved in rotorcraft/STOVL aerodynamics, dynamics and acoustics, provide greater knowledge of the detailed characteristics of these phenomena, and permit well-verified designs. Innovative developments with applications to tilt rotors, single main rotor and tandem helicopters, co-axial helicopters, and rotors with circulation control are needed to refine next generation rotorcraft and STOVL aircraft that will meet civilian global aviation requirements for quieter, more efficient, lower DOC aircraft. These requirements directly impact the enabling technology goals identified by NASA to support the agency's mission in rotorcraft. Examples of problems currently of importance include: efficient rotor design which reduce design cycle time, improved vehicle performance with reduction in ownership and operation costs, advanced active control strategies/methodologies for aeromechanics control and enhanced vehicle capability, innovative solutions to reducing airframe vibration, rotor vibratory loads, and radiated noise. New analysis methodologies addressing the unique aspects of civilian rotorcraft/STOVL aircraft through CFD/CSM/CAA for individual and integrated vehicle systems are also sought.

06.05 Viscous Flow Computation, Modeling, and Control
Lead Center: LaRC

NASA interest in viscous flow computation, modeling and control encompasses the entire spectrum of aerodynamic and aerothermodynamic phenomena that may be encountered by subsonic-to-supersonic aircraft and aerospace vehicles. The purpose of this subtopic is to advance the understanding of static and dynamic behavior, transient phenomena, maneuvering, stability and control, aerodynamic performance, heat transfer, and combustion phenomena. Applications include both external and internal flow fields and multiple body interactions; of interest are innovative ideas, (i.e., plasma flow control and its potential impact on vehicle performance). Areas of interest include the following:

- Flow-physics modeling and control of transition and/or transitional flows, turbulence, and turbulence-related phenomena such as heat transfer, skin-friction, acoustics, mixing and combustion.
- Control and/or mitigation of complex flow phenomena such as separation, vortical flows, including drag-due-to-lift, and shock wave drag.
- Numerical methods for solving fluid-flow equations that increase computational efficiency, accuracy, speed, and utility, including construction of new algorithms, improved computer languages, improved boundary condition procedures, efficient grid-algorithm interfacing, and applications of automation techniques. Additional considerations are grid-generation procedures, unstructured grids, solution-adaptive procedures, and grid quality measures.
- Analytical and numerical techniques that enhance the understanding of transition and turbulence phenomena and provide improved models to solve the Navier-Stokes equations.
- Scientists' workbenches with integrated, graphical tools for interactive geometry definition, grid-generation, flow visualization, and solution validation.
- Innovative scientific visualization includes techniques to identify and visualize the details of complex flow fields around 3-D aircraft.

06.06 Internal Fluid Mechanics for Aeropropulsion Systems
Lead Center: LeRC

Innovative concepts are sought for analysis, design, test and measurement technology which will allow significantly reduced design cycle time with improved design quality in aeropropulsion systems for low subsonic through hypersonic speeds. Areas of interest include the following:

- Inlets and nozzles: Advanced steady-state and time-dependent flow analyses as well as new instrumentation and visualization methods for flow fields including shocks, boundary layers, boundary-layer control, separation, heat transfer, surface cooling, jet mixing and noise prediction. Unsteady boundary condition models for the effects of upstream or downstream components.
- Turbomachinery: Advanced flow codes and physical models for both steady and unsteady flows including shocks, viscous effects, heat transfer and tip-clearance effects in fans, compressors, turbines and wave rotors. Novel concepts for instrumentation and flow visualization.
- Combustors: Highly efficient flow codes and novel measurement techniques for the flows and physical processes in a combustor or wave rotor passage including fuel injection, spray evaporation and mixing, reaction mechanisms and kinetic rates for hydrocarbon oxidation and soot formation, formation of solid and gaseous exhaust emissions and the effects of endothermic fuels in high speed systems.
- Computational methods for internal flows: Innovative algorithms and techniques for solving internal flow problems. This includes multiblock, unstructured and solution-adaptive grid schemes. New methods for solid modeling and grid generation. Software strategies to simplify the parallel implementation of the above methodologies. Intelligent software for pre- and post-processing, as well as aerodynamic design system integration and automation. New techniques for optimization of the aerothermodynamic performance of propulsion systems and components.
- Aeropropulsion systems simulation: New products for cost-effective computational simulation of both full systems and subsystems. Of particular interest are multi-level of fidelity analysis techniques that capture the appropriate physics at the appropriate fidelity for full system simulation and multidisciplinary techniques which facilitate multidisciplinary data exchange and integration with design systems, coupling of single discipline codes and multiphysics approaches.

06.07 Multi-Disciplinary Design Optimization and System Analysis of Aerospace Vehicles
Lead Center: LaRC

Multidisciplinary design optimization (MDO) is a collection of design-oriented analysis and systems optimization methods for the design of complex engineering systems and subsystems that exploits the synergism of mutually interacting phenomena. Advanced vehicles which are viable from both the performance and affordability standpoints often require delicate trade-offs between not only the traditional performance disciplines, such as structures, propulsion, aerodynamics, controls, electromagnetics, materials and flight decks, but also between them and such nontraditional disciplines as requirements, manufacturing, safety, cost and operations. MDO requires design-oriented tools, i.e. tools which augment the analysis result with sensitivity analyses (derivatives), approximations and/or rapid reanalysis capability. MDO also requires optimization methods and tools that can be used in conjunction with multidisciplinary analyses to assist engineers in developing improved designs. Systems analysis (SA) for aerospace vehicles involves assessing the impact of changes in mission requirements and/or technologies on systems design and operations of interdependent subsystems. Effective SA performed early in the design process can increase performance and reduce the potential for downstream design changes, thus minimizing cost increases and schedule slips. This subtopic seeks innovative proposals for application software embodying the mathematical and algorithmic aspects of both MDO and SA methods for aerospace vehicles, such as:

- Efficient, design-oriented, multidisciplinary analysis of complex physical models.
- Efficient, design-oriented multidisciplinary sensitivity analysis of complex physical models.
- Efficient tools to approximate system disciplinary or multidisciplinary responses using zero-, first- and possibly higher-order system information.
- Optimization methods for multidisciplinary systems with large numbers of design variables and constraints, and with both continuous and discrete design variables.
- Optimization methods that account for uncertainties in problem parameters.

- Incorporation of requirements definition, vehicle manufacturing, operations, safety and cost along with engineering design in MDO/SA.
- Enhanced weight-based and process-based cost-modeling methods.
- Vehicle sizing and scaling algorithms, with provisions for tracking the impact of technology improvements and the uncertainties associated with those improvements.
- Low-cost robust MDO/SA software suitable for small business.

06.08 Modeling & Simulation of Aerospace Vehicles
Lead Center: DFRC

Safer and more efficient design of advanced aerospace vehicles such as the X-33 and the High Speed Civil Transport require advancement in current predictive design tools. The goal of this subtopic is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influence of aerodynamics and the control system, in addition to pilot commands. The benefit of this effort will ultimately be increased flight safety (particularly during flight tests), more efficient aerospace vehicles, and an increased understanding of the complex interactions between the vehicle subsystems.

This subtopic solicits proposals for novel, multi-disciplinary, linear or nonlinear, dynamic systems simulation techniques. Proposals should address one or more of the objectives listed below:

- Prediction of steady and unsteady pressure and thermal load distributions on the aerospace surfaces, or similar distributions due to propulsive forces, by employing accurate finite element CFD techniques.
- Effective finite element numerical algorithms for multidisciplinary systems response analysis with adaptive three-dimensional grid/mesh generation at selected time steps.
- Effective use of high-performance computing machines, including parallel processors, for integrated systems analysis or pilot-in-the-loop simulators.
- Innovative applications of high-performance computer graphics or virtual reality systems for visualizing the computer model or results.
- Correlation of predictive analyses with test data or model update schemes based on measured information.

06.09 Hypersonic Airbreathing Propulsion & Vehicle Aerodynamics
Lead Center: LaRC

Innovative ideas and application of computational and experimental techniques are sought that will account for the complex aerothermodynamic, mixing, and combustion phenomena impacting the design and development of future space transportation vehicles, aero-assist orbital transfer vehicles, planetary entry probes, and hypersonic airbreathing propulsion systems. Applications include laminar, transitional, and turbulent nonreacting and reacting viscous flows and gas dynamics from continuum to free-molecule. Interest is in innovations resulting in improved and more efficient methods to define the aerodynamic performance, stability and control, heat transfer, and shear and pressure loads on future space transportation vehicles as well as to analyze engine flow path and to assess its performance. Phenomena of interest include, but are not limited to, equilibrium and finite-rate chemistry, thermodynamic and transport properties of multicomponent mixtures, gaseous radiation, gas-surface interactions, mixing and combustion, shock-wave/boundary-layer interactions, and laminar, transitional, and turbulent reacting flow modeling. Some examples include the following:

- Innovative concepts for hypersonic vehicles and airbreathing propulsion systems with potential for improved performance and reduced structural weight fraction.
- Numerical methods with enhanced accuracy and efficiency for solving fluid-flow equations for hypersonic vehicles and airbreathing propulsion systems.
- Advanced test techniques and flow diagnostics (including nonintrusive flow diagnostics and surface diagnostics) for developing definitive databases in hypersonic facilities, including shock-expansion pulse facilities.
- Global measurement techniques for pressure and heat transfer in high Mach number flows.

- Model fabrication techniques with reduced cost and construction time.
- Analysis, design, and optimization techniques and graphical user interfaces for hypersonic vehicles and airbreathing propulsion systems.

06.10 Intelligent Design Methods for Aerospace Vehicles
Lead Center: ARC

America's aerospace community must have revolutionary new system design tools to meet the demands of the 21st century. These include distributed design teams, greater product complexity, adaptation to lack of detailed knowledge early in the design process, and, most importantly, reduced design cycle time and cost. Fortunately, emerging information technology (such as soft computing, fuzzy logic, advanced algorithms, and artificial intelligence), integrated with traditional aerospace vehicle technologies, can enable the development of such revolutionary systems. NASA intends to lead the charge to develop the next generation of design tools, that will decrease current design cycle time and cost by 50%. These tools will interconnect the design, operations, maintenance, and training databases and will also lead to advances in teaming that change the current integrated product teams into integrated, multidisciplinary, geographically-distributed product teams. Specific technology areas include the following:

- Computational models using algorithmic and reasoning technologies as well as neural networks, fuzzy logic and genetic algorithms to allow improvements in the cost, speed, and robustness of high-fidelity physics-based analysis and design processes as well as intelligent agents to include cost discriminators from large amounts of parametric systems and mission data.
- Interactive graphic-based tools, machine-independent human/machine interfaces, including web-based technologies, to facilitate integration of disciplinary software in analysis and design processes, and, to direct, redirect and monitor process execution.
- Algorithmic and reasoning technologies to allow for collaborative environments including remote execution on geographically distributed and heterogeneous computer systems as well as frameworks to support establishment of collaborative and distributed design environments capable of optimally handling complex aerospace vehicle analysis and design processes.
- Interface standards and data protocols, technologies and systems for storage and query of variable fidelity, multi-source, multi-discipline design data sets, and techniques to present static and dynamic -3D datasets to ultimately maximize the potential for human direction of aerospace design and analysis processes. This technology includes AI-based agents for feature detection, and fuzzy-reasoning data selection and presentation.
- Instrumentation and test techniques that provide high fidelity global surface or global field design data, and knowledge-based processes/tools that result in reduced testing and flexible operations.
- Common parameterized geometry and discretization tools (e.g., computational grids) for all disciplines required in aerospace vehicle analysis and design.

06.11 Instrumentation, Sensors, and Controls for Propulsion and Power Systems
Lead Center: LeRC

Advanced technology concepts in instrumentation, sensors, and controls need to be developed to significantly improve overall aircraft safety, environmental compatibility, performance, affordability, reliability and durability.

- Advanced thin film, optical, and MEMS (Micro Electro-Mechanical Systems) sensors for use in aeropropulsion systems are needed for ground and flight applications. Air temperature, pressure, density, chemical species, and velocity measurements, and engine component surface temperature, pressure, strain, and deformation measurements are of interest. Reliability at high temperatures and pressures is a requirement. Compatibility with advanced propulsion system materials such as ceramics and composites is desired.
- High-temperature integrated electronics and sensors will be needed as advanced aircraft control systems move toward the use of electromagnetic actuators and distributed control architectures. Both signal-level and power-level electronics that can operate at high temperatures are needed. Silicon carbide is being developed as a semiconductor material for these applications. Innovations are sought in silicon carbide high purity crystal

growth and doping, integrated device and sensor fabrication with special emphasis on metallization and device packaging for use in high temperature hostile environments.
- Emerging MEMS technologies with application to novel multidisciplinary propulsion concepts and turbomachinery flow control problems are of considerable interest. Concepts which consider development and integration of MEMS based sensing and actuation devices and robust control logic into an overall integrated system with experimental validation of the integrated system will be emphasized.
- Advanced active control technologies for control of propulsion system components such as fan, compressor, combustor etc. are of considerable interest. Concepts which focus on integrated system development including novel sensing and actuation schemes will be emphasized. Of particular interest are advanced concepts in active clearance control.

06.12 Revolutionary Propulsion, Propulsion Systems and Components
Lead Center: LeRC

NASA seeks highly innovative concepts for propulsion, propulsion systems, and components for advanced aerospace vehicles including subsonic, supersonic, and hypersonic flight. The emphasis in this subtopic is high-risk technology areas that can revolutionize air travel and create new markets for U.S. industry. Propulsion system components include inlets, propellers, fans, compressors, combustors, turbines, nozzles, fuels, and recuperators and/or regenerators. Specific technical areas of interest include the following:
- Advanced cooling concepts that provide reduced coolant penalties. This can include innovative cooling systems, materials concepts, fuel cooling of the combustor, and endothermic fuels and/or fuel additives to increase the heat-sink capacity or cooling capacity of the fuels.
- Development of new fuels for air-breathing vehicles in the speed range of mach 0 (takeoff) to 25 that provide higher propellant density, net improvement in thrust efficiency, or thrust augmentation. Proposals should address analytic assessments of feasibility, practical demonstrations of fuel additive techniques using minimal/efficient/smart delivery systems, and/or demonstrations of thrust augmentation in nozzle test flows.
- Innovative concepts relating to the combustion process, including techniques to identify the onset of combustion instability in lean-burn, low-NOX combustors, designs to avoid instabilities, and active and passive combustion controls.
- Greater cycle efficiency with an emphasis on thermodynamic cycles including combined cycles. Specific examples include topping cycles, cycles which employ recuperators, and inlet flow conditioning which allows turbomachinery to operate at high speed flight conditions.
- Micro air-breathing propulsion systems and their integration into airframes, such as propulsion system integration into the skin of the wing or totally within the wing.
- Innovative concepts relating to injectors, mixing, and sprays for increased efficiency and performance, and reduced emissions. This also includes injection of gelled fuels into airbreathing engines.

07 Experimental Flight Research

Experimental flight research is an invaluable for exploring new concepts and for complementing and strengthening laboratory research. The subjects covered under this topic area are focused on (1) bringing innovative technology into flight research to explore new aerodynamic and airbreathing/rocket propulsion concepts and (2) radically improving the overall effectiveness of the flight research process. Aerodynamic areas of interest range from concepts applicable to hypersonic orbit insertion to low Reynold’s number high-altitude long duration atmospheric sampling applications. Propulsion areas of interest include entire system concepts which may incorporate combined propulsion cycles as well as innovative technology addressing system elements such as high density fuel, engine system components, or regenerative power systems.

07.01 Very High Altitude Aircraft Technology
Lead Center: DFRC

NASA currently has no subsonic flight capability above 70,000 feet. The physical properties of the atmosphere change quickly at altitudes above 80,000 feet, and atmospheric flight at such extreme altitudes poses significant challenges in several aerospace technology areas. This subtopic solicits innovative proposals that advance technologies toward the development of subsonic aircraft for sustained flight above 100,000 feet altitude. NASA is interested in an atmospheric sampling aircraft, manned or unmanned, with a high subsonic speed range, capable of at least three hours endurance at the high altitude with a 1000-pound payload. Specific areas of interest include:

- Over the horizon command and control systems.
- Collision avoidance systems for unpiloted or autonomous operations.
- High power density, regenerative power sources.
- High altitude subsonic aerodynamics, propulsion, structures and materials, aeroelastic and aeroservoelastic flight dynamics. Proposals for studies involving the development of specific design configurations are not of interest unless the contractor is proposing the feasibility of innovative concepts that have not been previously reported in the open literature.

07.02 Flight Sensors, Sensor Arrays and Airborne Instrumentation
Lead Center: DFRC

Real-time measurement techniques are needed to acquire aerodynamic, structural and propulsion system performance characteristics in flight and to safely expand the flight envelope of aerospace vehicles. The scope of this topic is the development of sensors, sensor systems, sensor arrays or instrumentation systems for improving the state-of-the art in aircraft ground or flight testing. The goals are to improve the effectiveness of flight testing by: simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, minimizing the disturbance to the measured parameter from the sensor presence, deriving new information from conventional techniques, or combining sensor suites with embedded processing to add value to output information. This subtopic solicits proposals for improving airborne sensors and sensor-instrumentation systems in subsonic, supersonic and hypersonic flight regimes. These sensors and systems are required to have fast response, low volume, minimal intrusion and high accuracy and reliability, and include wireless technology. Innovative concepts are solicited in the following areas:

Vehicle Environmental Monitoring
- Nonintrusive air data parameters (airspeed, air temperature, ambient and stagnation pressures, Mach number, air density, flow angle).
- Off-surface flow field measurement and/or visualization (laminar, vortical, and sepatated flow, turbulence) zero to 50 meters from the aircraft.
- Boundary layer flow field, surface pressure distribution, acoustics or skin friction measurements or visualization.
- Any of the above measurements in hypersonic flow.

Vehicle Condition Monitoring
- Optical arrays for robust flight control surface position and velocity measurement.
- Sensor arrays for structural load monitoring.
- Robust arrays for engine monitoring and control applications. Advanced instrumentation for aeropropulsion flight tests. Thin film and fiber optic sensors, especially those compatible with advanced propulsion system materials such as ceramics and composites, and capable of withstanding the high temperatures and pressures associated with turbomachinery.
- Onboard Processing for data condensation, failed sensor identification or other valuable on-board processing capability.

07.03 Hypersonic Vehicle Design and Systems Technology
Lead Center: LaRC

Innovative system-oriented research is sought to support, develop, and/or enable advanced hypersonic technologies that could impact the design and optimization of future hypersonic vehicles. The focus is on hypersonic airbreathing vehicles with emphasis on hypersonic cruise airplanes and single- or two-stage-to-orbit vehicles.

Design/analysis software/algorithms and graphical user interfaces to the software to address hypersonic vehicle design and performance prediction needs can include the following:

- Conceptual and preliminary design.
- Total multi-disciplinary configuration design and optimization.
- Three-dimensional methods for external and internal vehicle/propulsion flowpath analyses (includes CFD and closed form methods or a combination thereof).
- Vehicle sizing and scaling.
- Subsystems design/database including sizing, integration, and networking routines with or without power balance capabilities.
- Methods for design/analysis of cooled leading edges including heat load predictions.
- Inverse design methods.
- Trajectory design, analysis, and optimization.
- Aerodynamic performance prediction methods.

Advanced hardware and systems with the potential to reduce structural weight fraction and/or increase vehicle performance are sought and can include:

- Heat exchangers, reactors, and secondary coolant designs for endothermic fuel systems.
- Propulsion cycles applicable from Mach 0 to 25 and accompanying design and integration techniques.
- Heat-rejection radiators, compact, high-performance convective heat exchangers, and cooling panel design.
- Lightweight, durable coating or insulation systems that can significantly reduce the aerothermal heat load to external/internal surfaces with those improvements.
- MHD propulsion/flowpath.
- Systems for reduction of drag at hypersonic speeds
- Plasma augmented propulsion.
- Systems for reduction of aeroheating at hypersonic speeds
- Innovative flight controls.
- Specialized hypersonic fuel systems.

07.04 Integrated Propulsion Systems for Airbreathing Hypersonic Flight
Lead Center: LeRC

Innovative ideas and applications of computational and experimental techniques are sought that will facilitate the integration of elements such as ejector-ramjets, ramjets, scramjets, and rockets into systems such as an ejector-ramjet-based combined-cycle propulsion system. These systems should be capable of accelerating a vehicle to low-earth orbit or to a high mach number (such as M=8 to M=15) for cruise. Use of advanced turbo-ramjets and dry turbojets in turbine-based combined-cycle systems is also encouraged. System elements of interest include, but are not limited to, inlets, combustors, cowls, moving surfaces to change engine area ratios, seals, nozzles, instruments, sensors and controls. Specific areas of interest include the following:

- High thrust performance of ejector-ramjets or alternative elements at take-off of the hypersonic vehicle in either a vertical or horizontal orientation.
- Optimization of the flowpaths and transitions in operation, for an ejector-ramjet-based space launch system. This might include transitions from initial ejector-ramjet to ramjet, from ramjet to scramjet, and from scramjet to rocket.
- Use of internal fluid mechanics and computational fluid dynamics (CFD) techniques to accurately predict flows in all parts of the engine flow path from vehicle inlet surfaces to nozzle end-plane. Thermodynamic

cycle optimizations for engine cooling by propellants and detailed modeling of thermodynamic cycles with engine cooling.

- Optimization of the design and placement of propellant injectors and igniters throughout engine system; use of lightweight, durable techniques for flight-weight engine fabrication.
- Innovative instrumentation, sensors, and controls/control methodologies that are unique to airbreathing hypersonic propulsion systems, including optical techniques and thin-film, fiber-optic, and micro electro-mechanical systems (MEMS) sensors. Advanced, robust, and multivariable control technologies that lead to enhanced performance and reliability.
- Practical means of capturing air and separating the oxygen or enriching air during early phases of hypersonic air-breathing flight, for use during later stages, to improve overall flight performance and efficiency.
- Advanced technologies for integrated propulsion systems and propulsion/airframe integration not already mentioned above, such as pulse detonation-techniques for the low speed portion of operation of integrated air-breathing propulsion systems for hypersonic vehicles, or laser-driven/laser-assisted hypersonic airbreathing propulsion cycles.

New designs, design optimizations and manufacturing technologies that would advance the state of art in design, manufacture and the testing of minature propulsion systems for remotely controlled or autonomous micro-airplanes smaller than twelve inches wing span to be used for hypersonic research, remote sensing and/or observation. Some items of interest are turbines and turbine components such as combustors, fuel injectors and rotating components. Also of interest are miniature heat pumps, reciprocating engines and electric or solar powered motors. In addition, NASA is interested in the control systems that would allow efficient operation of minature engines.

- Techniques / methodology for experimental assessment of scramjet engine air mass capture in flight tests with proof-of-concept in ground tests.
- Techniques / methodology for experimental assessment of fuel-air mixing and reaction in scramjet flight tests with proof-of-concept in ground tests.
- Methodology for achieving geometric variations of engine flowpath, including fuel injectors, consistent with sequential airbreathing modes over wide Mach range.
- Flowpath improvements/optimizations to increase dual-mode scramjet performance for practical, integrated propulsion systems for hypersonic cruise or flight to orbit. Ideas to improve inlet efficiency/operability, fuel/air mixing and combustion efficiency, and nozzle flowpath energy recovery.
- Ground test techniques that enhance facility operation and enable experimental assessment / optimization of scramjet flowpaths at Mach 8 to 15.

8.2 HUMAN EXPLORATION AND DEVELOPMENT OF SPACE

The mission of the Human Exploration and Development of Space (HEDS) Enterprise is to open the space frontier by exploring, using and enabling the development of space and to expand the human experience into the far reaches of space. In exploring space, HEDS brings people and machines together to overcome the challenges of distance, time and environment. Robotic science missions survey and characterize other bodies as precursors to eventual human missions. In using space, HEDS emphasizes learning how to live and work there and utilize the resources and unique environment. In enabling the development of space, HEDS serves as a catalyst for commercial space development. And throughout, this Enterprise will employ breakthrough technologies and ingenious designs to revolutionize human space flight.

http://www.osf.hq.nasa.gov/heds/

08 Increase Knowledge of Nature's Processes Using the Space Environment

HEDS contributes to the creation of new scientific knowledge by conducting scientific investigations in several related areas. One area focuses on gravity-dependent phenomena using both Earth and space-based facilities. HED's basic research programs study the fundamental and direct relationship between gravity and certain biological, chemical and physical processes. In these investigations, gravity is used as an experimental variable much as temperature and pressure are in similar studies. The objectives of this topic include understanding the fundamental role of gravity and the space environment in biological, chemical, and physical systems.

08.01 Understanding and Utilizing Gravitational Effects on Molecular Biology and for Medical Applications
Lead Center: JSC

Microgravity provides a unique environment for new methods of processing biological materials that have medical applications or lead to spin-offs in medicine and biotechnology. Current space research includes: new methods for free-fluid, electric-field purification of living cells or proteins, development of space bioreactors for culture of fragile cells that have applications in biomedical and cancer research, tissue engineering systems which take advantage of microgravity to grow 3-D tissue constructs, testing the effectiveness of drugs and biomodulators on growth and physiology of normal and transformed cells, methods of growing large protein crystals and analysis of the three-dimensional structure to aid drug designs to mimic or inhibit the biological function of these proteins, and methods for measuring specific cellular and systemic immune functions of persons under physiological stress. Biotechnology research systems also are being developed for micro-g research on the International Space Station. Specific areas of interest are:

- New methods for culturing mammalian cells in bioreactors, including advanced bioreactor designs and support systems, miniature sensors (for measurement of pH, oxygen, carbon-dioxide, glucose, and metabolites within the cell culture fluid medium), and microprocessor controllers.
- Methods for separation and purification of living cells, proteins and biomaterials, especially those using electrokinetic or magnetic fields that obviate thermal convection and sedimentation, enhance phase partitioning, or use laser light and other force fields to manipulate target cells or biomaterials.
- Techniques or apparatus for macro-molecular assembly of biological membranes, bio-polymers, and molecular bio-processing systems; bio-compatible materials, devices, and sensors for implantable medical applications including molecular diagnostics, in vivo physiological monitoring and microprocessor control of prosthetic devices.
- Methods and apparatus which allow microscopic imaging and biophysical measurements of cell functions, effects of electric or magnetic fields, photoactivation, and testing of drugs or biocompatible polymers on live tissues.
- Quantitative applications of molecular biology, fluorescence image and flow cytometry, and new methods for measurement of cell metabolism, cytogenetics, immune cell functions, DNA, RNA, oglionuceotides, intracellular proteins, secretory products, and cytokine or other cell surface receptors.
- Micro-encapsulation of drugs, radiocontrast agents, crystals, and development of novel drug delivery systems wherein immiscible liquid interactions, electrostatic coating methods, and drug release kinetics from microcapsules or liposomes can be altered under microgravity to better understand and improve manufacturing processes on Earth. This includes methods for improving the controlled release from transdermal drug devices, ionaphoresis, controlled hyperthermia and new drug delivery systems for inhalation and intranasal administration.
- Miniature bioprocessing systems which allow for precise control of multiple environmental parameters such as low level fluid shear, thermal parameters, pH, conductivity, external electromagnetic fields and narrow-band light for fluorescence or photoactivation of biological systems.

08.02 Understanding and Utilizing Gravitational Effects on Animals
Lead Center: ARC

The interests of the Gravitational Biology and Ecology Program in this subtopic area will focus on technologies that aid the investigation of all phases of organism growth, development and their interactions with other organisms in the space environment. Such studies will range from organism development, including gametogenesis through fertilization, embryonic development and maturation, through ecological system stability. Studies may include a variety processes such as metabolism and metabolic control, through genetic expression and the control of development. Of particular interest are technologies that require minimal power, and can non-invasively measure physical, chemical, metabolic and development parameters. While such measurements will ultimately be made in environments at one or more of several gravity ranges: "microgravity" (10-2 to 10-6 x g), "planetary" gravity (1 x g (Earth); 0.38 x g (Mars) or 0.12 x g (Moon)) or hypergravity (up to 2 x g), refined and stable measurements are as important as gravity independence. Of interest are sustained instrument sensitivity, accuracy and stability, and reductions in the need for frequent measurement standardization. Parameters requiring measurement include: pH, temperature, pressure, ionic strength, gas concentration (O_2, CO_2, CO, NO_2, etc.), and solute concentration (e.g., Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, PO_4^{3-}, etc.). In the case of new techniques and instruments, a clear path toward miniaturization, reduction in power demands and increased spaceworthiness should be identified.

08.03 Understanding and Utilizing Gravitational Effects on Biotechnology and Materials Science
Lead Center: MSFC

NASA has interest in experiments that characterize and utilize the influence of microgravity on biotechnology processes and materials science. Areas of interest include protein crystal growth and structural analysis techniques, separation science and technology, advanced electronic and photonic materials research, metals and alloys technology, glass and ceramic materials technology. Another area relates to microgravity processing approaches such as containerless processing and advanced thermal processing techniques. Innovations are sought in the following:

- Electronic and photonic materials leading to solid-state detectors with improved properties, and controlled crystal growth for scientific and commercial applications. Metallic alloys with improved grain structures by directional solidification and processing involving supercooling and undercooling states.
- Polymers, composites, and other materials that incorporate sensory, effector, and self-repair technologies.
- Simulation capabilities that will elucidate the interaction of transport properties during liquid state processing and can lead to desired microstructures and properties. Experimental design methodologies combining advanced process models, optimization techniques, and control.
- Experiments and theoretical research in separation techniques and protein crystal growth for a greater understanding of such processes in the reduced-gravity environment of space.
- Instrumentation to determine the influence of crystallization parameters on the size and quality as well as growth rates of protein crystals that lead to commercial and medical applications.
- Mathematical modeling, new methods, materials, and techniques to exploit the potential of microgravity for the improvement and understanding of biochemical separation processes.
- Development of technology in eucaryotic cell biology that takes advantage of the unique microgravity environment(or simulated environment) for innovative approaches to drug screening, biological product production, or organ/tissue remodeling.
- Automatic drug separation and purification from plants and cell cultures grown under confined conditions anticipated for prolonged residence in microgravity or off-Earth habitats.
- Advancement of high-yield protein or recombinant drug expression systems that function in cultures grown under simulated microgravity.
- Experimental sample containment, instrumentation, or processing approaches that enhance scientific return or minimize impact to experiment samples. Two examples are (1) containerless processing to control impurities and nucleation sites or allow processing of reactive melts, and (2) provide rapid cooling of the sample to enhance microstructural analysis.

- Thermal insulation or heating approaches that enhance safety and use resources more efficiently.
- Microgravity furnace technology for minimizing power, enhancing thermal axial gradients, and improving quench performance, while maintaining flat solidification interfaces, and minimizing disturbances to the sample.
- Microgravity furnace instrumentation technologies to better understand sample health and experiment status while minimizing the instrumentation's effect on the sample.
- Methods for integrating the furnace with the sample containment system to allow fast, cheap microgravity experiments.
- Advanced modeling techniques that can simulate the slow translation of a sample container relative to a host furnace for gradient processing, rapid translation for quench, and the quench. Methods for simplifying this type of modeling process.
- Technology and instrumentation leading to the formation, interaction and synthesis of particulate materials on Earth and in planetary environments and their application to the establishment of extraterrestrial outposts.
- Materials and studies leading to applications in radiation shielding during human extraterrestrial exploration of space.

08.04 Exploiting Gravitational Effects for Combustion, Fluids, Synthesis, and Vibration Technology
Lead Center: LeRC

NASA seeks innovative proposals for products to improve the operation and safety of orbiting spacecraft based on chemical and physical processes that exploit the microgravity and partial gravity environment. Also sought are products for application to NASA missions involving Mars and the Moon and for ground-based application and commercialization based on principles, understandings, or testing in simplified, non-convective microgravity and partial gravity fields.

For some demonstrations to support product development, the NASA Lewis Research Center can provide access and assistance to outside investigators in its unique facilities, including the Space Experiment Laboratory, the 2.2-second and 5.2-second drop towers, and parabolic-trajectory (20 seconds of low gravity) aircraft. (See Section 5.14) Specific areas of interest are:

- Products based on combustion or related chemical reactions in gaseous, liquid, solid, or mixed phases for application to spacecraft operational needs or to derived ground systems, aided by principles, models, or demonstrations validated in the simplified environment of microgravity and partial gravity.
- Products based on physical contact or transport in fluid, dispersed, or mixed phases for application to spacecraft operational needs or to derived ground systems, aided by principles, models, or demonstrations validated in the simplified environment of microgravity and partial gravity.
- Small-scale intermetallic, ceramic, or similar products produced through combustion synthesis in solid, filter-flow, thermite, or other reactions, with product uniformity, composition, or yield controlled or improved by exposure to the non-convective microgravity and partial gravity environment.
- Products to measure, isolate, or control acceleration, vibration, or jitter for application to spacecraft operational needs or to space experiment payloads or to derived ground systems.
- Sensors, instrumentation, and diagnostics systems for application to non-disturbing measurement of chemical, thermal, or flow parameters in microgravity and partial gravity or to derived ground systems, based on principles, models, or demonstrations validated in microgravity or partial gravity.
- Products to promote or improve fire safety through prevention, detection, suppression, or post-fire restoration for application to spacecraft or to derived ground systems, aided by principles, models, or demonstrations validated in microgravity or partial gravity.
- Transport phenomena associated with chemical process technologies and chemical separation processes in microgravity and partial gravity as well as in the Earth-bound environment.
- Technology that explains, enables or improves combustion and fluid processes in partial gravity environments to promote application of these processes to NASA's missions involving Mars and/or the Moon.

08.05 Understanding and Utilizing Gravitational Effects on Plants
Lead Center: KSC

The focus of this subtopic for the Gravitational Biology and Ecology program is improved understanding of the role of gravity on plants. This requires innovative support equipment for observing, measuring, and manipulating the responses of plants to environmental variables. Areas of specific concern and emphasis include:

- Measuring the atmospheric and radiation environment and optimizing the lighting and nutrient delivery systems for plants.
- Innovative approaches to storage, transportation, maintenance, and *in situ* analyses of seeds and growing plants.
- Sensors with low power requirements and low mass to monitor the atmosphere and water (nutrient) environment, as well as automated control and data logging systems for the experiment containers to measure performance indicators such as respiration (whole plant, shoot, root), evapotranspiration, photosynthesis, and other variables in plants.
- Variable gravity centrifuge capabilities with monitoring and environmental controls identical to the stationary component.
- Data analysis and control.
- Expert data management systems.
- Modular seeding and/or planting units to minimize labor.
- Sensors for atmospheric, liquid and solid analyses, including atmospheric and liquid contaminants such as ethylene and other biogenic compounds as well as analyses of hydroponic and solid media for N, P, K, Cu, Mg and micronutrients.
- Capabilities for specimen storage, manipulation and dissection.
- Video-image analysis for plant health.
- Sensors for primary environmental parameters and microbial organisms.
- Remote sensors to identify biological stress.
- Expert control systems for environmental chambers.
- Biotelemetry monitors and biological monitors carried on remotely controlled spacecraft.

09 Explore and Settle the Solar System

The International Space Station Program and Mars Exploration studies have defined technology and research needs that are critical to their individual goals. These include: research on human adaptation to the space environment; regenerative and bioregenerative life support; telerobots and robot assistants; space and planet surface suits; utilization of indigenous resources for propellants, life support consumables, radiation protection, and construction materials; micro- and nano technologies, manufacturing processes, and advanced materials. All are sought to enable humans to live and work in space or on a planet, to enhance performance, reduce cost, and maintain the health and well being of the crew.

09.01 *In-Situ* Resources Utilization (ISRU) of Planetary Materials
Lead Center: JSC

Significant benefits for future human missions to the Moon, Mars, and other planetary bodies may be attained by making maximum use of local, indigenous materials as a source for propellants, life support consumables, radiation protection, and construction materials. By pursuing the philosophy of "Make what you need at the planet instead of bringing it all the way from Earth", *in situ* resource utilization (ISRU) can result in reduction of mass requirements for the exploration mission, reduction in risk, and reduction in cost of the mission. It can also enable industrial and commercial participation in planetary exploration and expand human presence on the planet surface. One example of *in situ* propellant production employs the hydrogen reduction process for extracting oxygen from lunar minerals and glass. In addition, a number of techniques have been proposed for extracting and storing oxygen from the carbon dioxide atmosphere of Mars. In general, these processes require a number of subsystems, each of which could benefit from innovative approaches and technology advances. It is also possible that water could be extracted from permafrost deposits located at shallow depths in some locations on Mars. Key goals are to minimize the mass which must be brought from the Earth (including the equipment required to move or process the material), minimize power consumption, be truly innovative and not already in the literature. Areas for investigation of specific methods and processes for *in situ* resource utilization include the following:

Surface Resources:

- Methods and systems for extracting, processing, and manufacturing in-situ materials that can be used for construction of habitable structures on the moon or Mars. New methods for constructing buildings, radiation shielding structures, and tunneling techniques are needed. Novel methods for underground development of habitable structures (perhaps using natural features such as caves or lava tubes) on the moon or Mars are also needed.
- Methods for processing surface materials into useful equipment (e.g. solar panels, radio antennas, replacement parts etc.) which require no further manufacturing or assembly.
- Methods and systems for digging, sorting, mineral separation, and transporting lunar regolith or other materials to a reactor. Such systems should be lightweight, efficient, and capable of operating with minimal human supervision.
- Methods for extracting oxygen from lunar regolith that are power efficient and require a minimum of Earth-supplied reagents and consumables. Alternatives and improvements to previously-studied methods, such as reactors that expose lunar regolith to hydrogen gas at elevated temperature, are of interest. However, emphasis should be placed on innovative designs that minimize power requirements.
- Microbial methods for extracting oxygen, decomposing water, and extracting solar wind hydrogen from soils (typically present on the moon at 50 parts per million levels) from the Moon or Mars as an attractive alternate approach to propellant and consumable production.
- Methods for digging, extracting, and collecting water (including that which may be trapped in permafrost) that may be present on the surface or subsurface of Mars, which minimize power requirements and equipment mass which must be brought from Earth.

Atmospheric Resources:

- Methods to condense water vapor from the Mars atmosphere that are low mass or can be constructed from local materials with a minimum of equipment that must be brought from Earth.
- Microbial methods for extracting oxygen from the Mars atmosphere, or for decomposing water.
- Innovative processes and alternative approaches for extracting propellants and/or consumables including oxygen from the Mars atmosphere which have low power requirements and minimize the amount of equipment that must be brought from Earth. Processes currently being investigated include Sabatier/water-electrolysis reactor, reverse water gas shift reactor, and solid-oxide electrolysis (zirconia) cells. Oxygen extracted from the Mars atmosphere may be used for: production of propellant for transportation systems, production of oxygen for life support system gases, and production of cryogenics for extravehicular activity suits. Systems should be capable of operating autonomously, independent from continual earth-based control. Current scenarios for Mars exploration envision the following production needs for ascent oxygen propellant to support a single mission: 1 to 2 metric tonnes (for Mars robotic missions) and 30 to 40 metric tonnes (for Mars human missions).

09.02 Spacecraft/Habitat Monitoring, Safety, and Radiation Protection
Lead Center: JSC

Manned space missions require a variety of environmental monitoring and biomedical activities to protect crew health and to counter the effects of space on human physiology. Research disciplines include cell biology, clinical chemistry, endocrinology, immunology, hematology, microbiology, muscle physiology, pharmacology, nutrition, radiation biology, toxicology, and air and water quality. Quantitative assessments require innovative, space-flight compatible approaches in clinical laboratory operations, environmental health monitoring and maintenance of crew health. Special requirements for long-term operations of monitoring systems and data management arise from manned operations in the International Space Station. Areas in which innovations are solicited include the following:

- Assessment of the overall acceptability of the environment for human habitation and methods for assessing associated risks and thresholds for unacceptable contamination levels.
- In-flight monitoring of the chemical, microbial, and physical quality of the spacecraft environment, including recycled water, atmosphere, food, and surfaces. Of particular interest are the detection, identification,

quantitative measurement, and removal of organic contaminants and the assessments of potential health-effects for low level contamination in recycled water and air.
- Real-time and quantitative broad spectrum or target compound-specific analyzers for trace contaminants in spacecraft atmospheres and/or recycled water. The instrument must be compact, feature low power consumption, low maintenance, highly automated (requiring minimal crew intervention) and must be functional for long periods of time.
- Real-time and quantitative broad spectrum or target compound-specific analyzers for trace contaminants in spacecraft atmospheres and/or recycled water. The instrument must be compact, feature low power consumption, low maintenance, highly automated (requiring minimal crew intervention) and must be functional for long periods of time.
- Maintenance of microbial quality of the atmosphere, water and surfaces during spaceflight and means of assessing their effectiveness, including new, clinical microbiology methods for rapid identification of pathogens, methods for measuring biofilms and novel systems for sterilization.
- In-flight monitoring of non-ionizing, neutron and charged-particle radiation for determining interior and exterior environment of manned spacecraft, organ doses and the cytogenetic and carcinogenetic effects of protons and heavy ions, especially at low doses; measurement of effectiveness of radio-protectants and development of new biological and chemical radio-protectants against acute and late effects cellular effects of particulate and high energy cosmic radiation at cellular and organism level; development of biomarkers and amplified assays for measuring radiosensitivity and genetic damages by charged particles in human cells; development of computer biophysical models for organ dose calculation and for extrapolation of radiation data from cell to organism and from animal to human.
- Miniaturized optical sensors (infrared, ultraviolet, or visible light), electrochemical sensors, and biological sensors for measuring chemical contaminants in the atmosphere or water systems. These sensors are used for providing outputs for caution and warning, support of control functions, or safety precautionary measures.
- Microsensor devices capable of multifunctional monitoring of various chemical species or combined chemical/biological species in either air or aqueous medium. Of particular interest is the development of sensors that do not require calibration, are reversible with no or at least reproducible hysteresis, are sensitive over a two decade range of concentration (ppm), can operate in real-time fluid-flow conditions and for extended periods (months) of time. Chemical species of interest include formaldehyde, carbon monoxide, mercaptans, ethanol, acetaldehyde, and amines in air and organic species such as urea, acetic acid, amines and inorganic species such as nitrate, phosphate, magnesium, iron, zinc and potassium in water.

09.03 On-Board Human Health Maintenance and Countermeasures
Lead Center: JSC

Human presence in space requires an understanding of the effects of microgravity and other components of the space environment of the physiological systems of the body and on the psychology of the crew. Countermeasures must be developed to oppose the deleterious changes that occur in space or upon return to Earth. Health care and medical intervention also must be provided over extended duration missions. As launch costs are extremely sensitive to mass and volume, sensors and instruments must be small and light with an emphasis on multi-functional aspects. Low-power consumption is a major consideration, as are design enhancements to improve the operation, design reliability, and maintainability of these instruments in microgravity. As the efficient utilization of time is extremely important, innovative instrumentation setup, ease of usage, improved astronaut (patient) comfort, non-invasive sensors, and easy-to-read information displays are all-important considerations.

Health Monitoring and Countermeasures:
- Methods and equipment to maintain and assess levels of aerobic and anaerobic physical capability.
- Methods to monitor physical activity and loads placed on different segments of the human body.
- Exercise equipment able to load the musculoskeletal and cardiovascular systems and monitor, record, and provide feedback about performance.
- Approaches for sustaining, maximizing, assessing, and modeling individual as well as team performance.

- Countermeasures against deleterious changes in body systems in flight or upon returning to the ground. Changes include space adaptation syndrome effects such as space motion sickness, in-flight loss of muscle and bone mass, post-flight orthostatic intolerance, and post-flight reduction in neuromuscular coordination.
- Assessment of gas bubble formation or growth in the body after in-flight or ground-based decompression, and to prevent or minimize associated decompression sickness.
- Means to apply artificial gravity and reduce deleterious effects associated with short-arm centrifuges.
- Approaches to achieve health care and intervention within the operational constraints of space flight, including pharmaceuticals having extended shelf-life, diagnostic methods and procedures, medical monitoring, dental care and surgery, and blood replacement technology.
- In-flight procedures and techniques for assessing the human metabolism of proteins, carbohydrates, lipids, vitamins, and minerals.
- In-flight specimen collection and analysis to evaluate physiological and metabolic and pharmacological responses of astronauts. Non-invasive methods to measure crew performance and related factors.
- Novel software methods for documentation, storage, retrieval, analysis, and diagnosis of crew health.

Sensors and Instrumentation:

- Instrumentation to used for in-flight and ground-based studies for reliable and accurate non-invasive monitoring of human physiological functions such as the cardiovascular, musculoskeletal, neurological, gastrointestinal, pulmonary, immuno-hematological, and hematological systems
- Improve non-invasive methods to evaluate the functioning of the cardiovascular, neurological, musculoskeletal, and pulmonary systems.
- Non-invasive instruments to provide quantitative data to establish the effectiveness of an exercise regimen in ground-based research.
- Smart sensors capable of sensor data processing and sensor reconfiguration.
- Ultrasonic doppler systems for blood flow analysis.
- Virtual medical instrumentation.
- Automated biomedical analysis.
- Microgravity blood, urine, and respiratory gas analyzers.
- Microgravity refrigeration systems for the storage of biological samples and incorporating refrigerants acceptable for use in a spacecraft environment.

09.04 Spacecraft Life Support Infrastructure
Lead Center: JSC

Advanced life support systems are essential for the success of future human planetary exploration. Striving for self-sufficiency and autonomous operation, future life support systems will integrate physical and chemical processes with biological processes, resulting in hybrid systems. These hybrid systems, which include plant growth systems for the production of food and oxygen and utilization of recovered wastes, represent an additional closure of regenerative life support systems to further reduce mass and to promote self-sufficiency. Requirements include operability in micro-and partial-gravity, high reliability, minimal use of expendables, ease of maintenance, and low system weight and power. Innovative, efficient, practical concepts are desired in all areas of regenerative physicochemical and biological processes for the basic life-support functions of air revitalization, water reclamation, waste management, plant food production, and sensors and controls. Also innovative, cost-effective concepts are desired to assess, predict, control and enhance the effect of microgravity and partial-gravity on the operation and performance of physicochemical and biological life support technologies including approaches to safely integrate flight experiments into the International Space Station. In addition to these space exploration related applications, innovative regenerative life support approaches which could have terrestrial application are encouraged. Proposals should strive to conduct Phase II experimental development that could be integrated into a functional life support system. Areas in which innovations are solicited include the following.

Air revitalization:

- Oxygen, carbon dioxide, and water-vapor concentration, separation, and control techniques.

- Separation of carbon dioxide from a mixture primarily of nitrogen, oxygen, and water vapor to maintain concentrations of carbon dioxide below 0.3 % by volume.
- Separation of nitrogen and oxygen from carbon dioxide to reduce concentrations of nitrogen and oxygen to less than 0.2 % by volume.
- Removal of trace gases with regenerable sorbent beds, improved oxidation techniques or other methods.

Water Reclamation:

- Efficient, direct treatment of waste water (e.g., urine, wash water, and condensates) without requiring expendables to produce potable and hygiene water including stabilization of waste water and purge gases prior to storage, processing, or overboard-venting. In particular, processes are required that reduce impurities in composite waste streams from greater than 500 PPM total organic carbon (TOC) content to less than 0.25 PPM TOC and inorganic salts from greater than 1000 PPM dissolved solids to less than 50 PPM.
- Removal of ammonium ion from bioreactor process effluent streams from 500 PPM to less than 0.25 PPM.
- Potability maintenance techniques.
- Post-treatment of processed water by *in situ* organic removal from 100 PPM TOC to less than 0.25 PPM TOC and removal of microorganisms from ten million CFU per ml to one CFU per ml.
- Recovery of water from wastewater concentrates (i.e., brine from reverse osmosis).
- *In situ* cleaning and sterilization of potable water systems.
- Removal of sodium chloride from waste water (i.e., bioreactor effluent, reverse osmosis brine, etc.) to less than 10 PPM to enable it's use in plant growth nutrient solutions.

Waste Management:

- Biological and physicochemical technologies for recovering resources (e.g., carbon dioxide, water, nitrogen, hydrogen, etc.) from wastes (trash, plant biomass, human solid wastes, etc.). Functions to be performed are: waste stabilization and pretreatment, processing of the wastes, and product and by-product post-treatment. Waste processing technologies include incineration, aerobic biodigestion, anaerobic biodigestion, wet oxidation, supercritical oxidation, steam reforming, electrochemical oxidation and catalytic oxidation. Product and by-product post-treatment technologies should eliminate undesirable by-products such as nitric oxide and sulfur dioxide.
- Treatment of laboratory, metabolic, and other wastes for storage.
- Microbial techniques for waste treatment in micro- or partial-gravity.

Plant Growth and Food Production:

- Crop/Plant production systems required for the growth of plants for food and/or contributing to the reclamation of water, purification of air, and recovery of resources. Examples of such systems include: 1) sources for plant lighting such as high-efficiency lamps or solar collectors; 2) transmission and distribution systems for plant lighting including luminaires, light pipes and fiber optics; and 3) nutrient delivery systems, including hydroponics, solid substrates and materials for germination and wicking.
- Mechanization and automation of propagation, seeding, and plant biomass processing. Plant biomass processing includes harvesting, separation of inedibles from edibles, cleaning and storage of edibles (seed, vegetable, and tubers) and removal of inedibles for final resource recovery processing.
- Heat removal techniques for the plant growth lighting.
- Facility or system sanitation methods to prevent excessive build-up of microorganisms within nutrient delivery systems.
- Food and surface disinfectant system (i.e. hydrogen peroxide generator)
- Health measurement of plant growth systems from parameters such as rate of photosynthesis, transpiration, respiration, nutrient uptake. Data acquisition should be non-invasive or remotely sensed using spectral, spatial, and image analysis. System modeling and decision-making algorithms may be included.

Sensors:

- Sensors emphasizing accuracy, operational reliability, real-time multiple measurement functions, in-line operation, self-calibration, and low energy consumption for monitoring and control of the life support processes. Species of interest include nutrient composition of plant growth hydroponic delivery systems, dissolved gases and ions in water reclamation processes, and atmospheric gaseous constituents including trace gases in air revitalization processes. Both invasive and non-invasive techniques will be considered.

09.05 Space Crew Performance Enhancements and Accommodations
Lead Center: JSC

The goal of this subtopic is improving crew and ground operations performance and productivity in a system context; documenting the cost-effectiveness of the improvements; and developing innovative concepts in crew accommodations and equipment required to support complex, future manned space missions including missions of 5 years without resupply. Desired products include innovative hardware and software to enhance ground support operations and training, and in-flight operations and environment. Specific areas for innovations include:

Human Factors:

- Advanced methods for collection and analysis of human performance with minimal human operator involvement. For example, methods of tracking body motion in 6 DOF without elaborate markers, setup, calibration or environmental constraints; automatically identifying categories of performance from videotaped records, such as time spent at a given task, time spent in translation, time spent in interaction with other crew members.
- Technologies or tools to evaluate, measure or enhance habitability, including spacecraft interior layout; illumination and material reflectivity; lightweight acoustic control methods. An area of special interest would be in techniques for reconfiguring spacecraft habitable areas, including stowage, galley, sleep compartments, waste management systems, etc., for optimal use in both micro-g during transit to a planetary surface, and in partial-g on the planetary surface.
- Technology, development tools, and quantitative methods for designing, evaluating and/or enhancing human interfaces with computers and information systems (e.g., displays, access methods) or remotely controlled systems (e.g., tele-operations, augmented feedback).

On-board Crew Support Systems:

- Novel food and/or food systems for microgravity including food processing, engineering an a shelf life extension of at least 3 year; packaging and preservation technologies which minimize waste; improvements in acceptability; ease of handling in microgravity; food safety.
- Processing and preparation of chamber grown wheat, rice, soybeans, sweet potatoes and potatoes into foods. Conversion to ingredients such as sugar and oil, as well as final products, including meat and dairy analogs, with emphasis on automation and utilization of food waste.
- Personal hygiene systems in a zero-gravity environment. Examples: total body cleaning, hair grooming, cleansing agents compatible with closed-loop life support systems. -Personal crew equipment: flame and soil resistant clothing, portable lighting, safety and emergency equipment, and body and equipment restraints.
- Housekeeping for zero-gravity including: habitat cleaning, trash management, apparel cleaning, particulate reduction and control, and cleansing agents compatible with closed-loop life support systems.
- Tools, techniques, software for an in-flight maintenance system to maintain complex systems. Includes: expert diagnostics, in-flight manufacturing tools/techniques.
- development of a hand held digital Single Lens Reflex type camera system with 32 bit color, ISO sensitivity range from 100 - 3200, image resolution equal.

Crew Training and Ground Operations

- Training and tutoring systems for mission operations support, including distributed cooperative training, virtual reality training, intelligent computer-based training, and authoring tools. Procedures or technology for evaluating effectiveness of different training methods.

In addition, NASA seeks innovative data analysis technologies to support human space missions. Among these will be long duration missions throughout the solar system and the continually operating International Space Station. A small number of crewmembers, aided by intelligent robots, will deal with large quantities of highly complex and critical information. Ground support will be limited by communications constraints and by budgetary constraints. Proposals are sought in the following areas:

- Immersive environments: real-time environments to enhance a human operator's ability to interact with large quantities of complex data, especially at distant locations.
- Intelligent data analysis techniques: capable of interpreting, explaining, exploring, and classifying large quantities of heterogeneous data.
- Intelligent software agents: goal-driven data analysis systems capable of adaptation and learning, and of collaborating with other agents and people.
- Simplified user interfaces, including natural language interfaces.

Systems Automation for Human Space Vehicles:
Long duration space missions, as the International Space Station and missions to the Moon and Mars, will require an unprecedented degree of systems automation and maintainability. A key element in human space flight is the effective utilization of the crew members time and decision making ability. Functions should be routinely delegated to autonomous systems except when crew analysis and decision making are required. Specific areas of interest include the following:

Planning, Scheduling, and Resource Management
- Management of the actions of subsystems within the larger context of system flight rules and constraints.
- Onboard planning, sequencing, monitoring, and re-planning of activities, including systems and crew activities.

Onboard Data Management
- Methods for selecting and summarizing vehicle systems and payload data for crew and for ground consideration.
- Autonomous calibration of sensors and instruments.

Fault Detection and Recovery
- Support for developing and operating autonomous fault protection systems, with provision for crew oversight.

Onboard Software Architectures and Operating Systems
- Onboard operating systems and architectures for hosting software for crew-supervised autonomy.

Design, Testing, and Validation Tools
- Languages, environments, simulation tools for use in designing and testing autonomous and crew supervised autonomy systems.

09.06 Human Space Mission Thermal Control
Lead Center: JSC

Future human space missions will operate in more severe environments than in the past. There is a need for highly efficient, lightweight, low power and reliable internal and external active thermal control systems for piloted spacecraft, rovers and planetary bases. Areas in which innovations are solicited include the following:

- Fault tolerant fluid to fluid heat exchangers that cannot fail in a way which permits leakage between fluid loops
- Heat pumps to acquire waste heat at near 0 degrees C and reject the heat via a radiator at approximately 50 degrees C
- Internal heat pumps to provide cabin dehumidification with a fluid heat sink of 15 to 25 degrees C
- Flexible radiators which can be stowed compactly for transport and deployed for use
- Micro-meteoroid tolerant and freeze/thaw tolerant radiators
- Environmentally friendly, non-toxic single and two-phase working fluids that either freeze below 75 degrees Kelvin or do not significantly change density upon freezing or thawing
- Two-phase heat transport loops and associated controls

- Interactive, user-friendly, graphical computation techniques utilizing state-of-the-art low-cost work stations for analysis and prediction of performance for thermal and fluid systems
- Thermal energy storage systems · Controllable water evaporator heat rejection devices for use in vacuum environments

* Note: thermal control innovations are also sought under the Plant Growth and Food Production section of the Spacecraft Life Support Infrastructure subtopic and under the Thermal Control subtopic in the Power, Propulsion, and Thermal Technology topic.

09.07 Cryogenic Fluids, Handling, and Storage
Lead Center: LeRC

Component or concept proposals are being solicited to improve the performance, operating efficiency safety and reliability of cryogenic fluid storage and handling in all gravity environments (10^{-6} g to 1 g) and Martian surface environments (i.e., dust, CO_2 atmosphere). Tanks of high energy propellant fluids, stored in their most efficient state, as low pressure subcritical cryogenic fluids are susceptible to fluid loss through environmental heating. Novel concepts are being solicited to significantly reduce the heat conduction through tank supports and penetrations and reduce solar radiation losses with insulating materials or by intercepting shields. The ability to transfer cryogenic liquids in nominal, reduced and low gravity conditions from storage vessels or production facilities to user tankage is also critical. Cryogenic fluids are used for life support, propulsion, and power systems. Innovations in the following areas are needed:

- Lightweight, low thermal conductivity cryogenic tank strut and support concepts.
- Low thermal conductivity cryogenic tank penetrations, i.e., instrumentation feed-throughs, feedlines, vent lines.
- Lightweight, insulating thermal protection schemes.
- Robust insulation concepts for multiple launch/landing and ambient/vacuum pressure cycles.
- Devices for vapor free acquisition of cryogenic liquids. · Small, low power, lightweight (2 liter/minute) liquid oxygen transfer pumps.
- Tank pressure control (e.g., thermodynamic vent) and/or integrated tank boiloff control and product liquefaction technologies.
- Lightweight mechanical fittings and flexhoses with low heat leak.
- Autonomous cryogenic disconnects and couplings.
- Flowmeters and densitometers for measurement of densified, multi-phase cryogens at flow rates of 1.4 to 5.6 liters per second.
- Instrumentation for monitoring cryogens in low gravity including mass quantity gauging, liquid-vapor sensing and free surface imaging.
- Cryogenic Pumping Systems without cryogenic seals. As an example, magnetically coupled pumps that can handle Liquefied Natural Gas (LNG), Liquid Oxygen (LO_2) or Liquid Hydrogen (LH_2). Magnetically coupled pumps eliminate one of the significant leak potentials in today's ground systems.
- Cryogenic Quick Disconnects are particulate sensitive. Mating these disconnects remotely raises concern of seal damage and subsequent leaks at cryogenic temperatures. QDs in all sizes (0.25 to 10.0 inch diameter) are needed for future exploration missions and future launch vehicles.
- Cryogenic Couplings are also particulate and scratch sensitive. Development of robust sealing couplings that are compatible with cryogenic temperatures and Liquid Oxygen compatible are also needed for future exploration missions and future launch vehicles. Diameters of 0.25 to 10.0 inches

09.08 Extravehicular Mobility/Activity
Lead Center: JSC

Advanced extravehicular activity (EVA) systems are necessary for the successful support of future human space missions. Complex missions require innovative approaches for maximizing human productivity and for providing the capability to perform useful work tasks. Requirements include reduction of system hardware weight and volume; increased hardware reliability, durability, and operating lifetime (before resupply, recharge and maintenance, or replacement is necessary) reduced hardware and software costs; increased human comfort; and less-restrictive work performance capability in the space environment, in hazardous ground-level contaminated atmospheres, or in extreme ambient thermal environments. All proposals must lead to specific Phase II experimental development that could be integrated into a functional EVA system. Innovations sought include the following:

Environmental Protection:
- Radiation protection technologies that protect the suited crewmember from radiation particles.
- Puncture protection technologies that provide self-sealing capabilities when a puncture occurs and minimizes punctures and cuts from sharp objects.

- Dust and abrasion protection materials to exclude dust and withstand abrasion.
- Thermal insulation suitable for use in low ambient pressure, but not vacuum, environment.

EVA Mobility:
- Space suit gloves, produced with size-reproducible manufacturing processes, that provide highly dexterous hand, fingers, and thumb mobility and tactile sensitivity, and that incorporate active thermal control capability for removing and/or adding heat depending upon external ambient thermal conditions and hand-grasp surface temperature.
- Space suit soft joints that provide dual-axis capability and low torque in rotational components and that also minimize stowage volume, and that are lightweight, low cost, and large range.
- Space suit shoulder that can accommodate large range of suit pressures from 3.5 to 8.3 psi, is low torque, lightweight, and low cost.
- Space suit low profile waist bearing that maximizes torso rotation that is necessary for partial gravity mobility requirements and is also lightweight and low cost.

Life Support System:
- Long-life and high-capacity chemical oxygen storage systems for an emergency supply of oxygen for breathing, such as:
    - Chlorate candles that provide reliable backup oxygen supply.
    - Potassium superoxide/fullerine stowage of oxygen to reduce volume.
- Low-venting or non-venting regenerable individual life support subsystem(s) concepts for crewmember cooling, heat rejection, and removal of expired water vapor and carbon dioxide.
- Fuel cell technology that can provide power to a space suit.
- Convection and freezable radiators that will be low cost and weight for thermal control.
- Water membrane evaporator that can provide reliable cooling at Mars pressure.
- Microencapsulated wax and carbon brush garments that provide direct thermal control to crewmember.
- High reliability pumps and fans.
- CO_2 and humidity control devices which, while minimizing expendables, function in a CO_2 environment.

Sensors/Communications/Cameras:
- Information displays and input and output interfaces for use by the EVA-suited individual, including displays for obtaining status information of and/or controlling systems performance or work-task related equipment.
- CO_2, bio-med, and core temperature sensors with reduced size, lightweight, increased reliability, and packaging flexibility.
- IR camera that displays temperature of environment for safe handling of objects and are integratable into a spacesuit.
- Visual camera that provides excellent environment awareness for crewmember and public and are integratable into a spacesuit.
- Microphone on glove that detects flows and proper operation of equipment by glove sound sensors.
- Mini-mass spectrometer that detects N_2, CO_2, NH_4, O_2, and hydrazine partial pressures.

- Radio/laser communications that provides good communications among crew and base.

Integration:
- Robotics interfaces that permit autonomous robot control by voice control via EVA.
- Minimum loss airlock providing quick exit and entry.
- Recharge and checkout systems that lower EVA overhead time for crew.
- Work tools that assist the EVA crewmember during movement in zero-gravity and at worksites. Specifically, devices that provide temporary attachments, that rigidly restrain equipment to other equipment and the EVA crewmember, and that contain provisions for tethering and storage of loose articles such as tool sockets and extensions.
- Surface mobility devices for EVA crewmembers.

09.09 Robotics
Lead Center: JSC

Proposals are solicited for innovative concepts that will both increase robotic dexterity manipulation capabilities, and reachability, and also increase capabilities for humans to interact with and to control robotic systems to perform on-orbit operations while minimizing the workload to EVA and IVA astronauts, and ground operators:

Robotic Manipulators, End Effectors, and Joints
Proposals are sought which include improvements to robotic joints, actuators, end-effectors, tools, and mechanisms. Proposals should address issues associated with space compatibility. Specific areas of interest include the following:
- Increased power to weight ratio and reduced scale actuators including magnetostrictive motors and synthetic muscles.
- Miniaturized actuator control and drive electronics.
- Miniaturized sensing systems for manipulator position, rate, acceleration, force and torque.
- Robotic grasping and handling systems that accommodate existing EVA tools including, human-sized multi-fingered dexterous end-effectors.
- Anthropomorphic systems.
- Tools, fastening systems, and fluid connectors that accommodate both EVA astronauts and robotic systems.
- Sensor-guided tools providing higher precision or lower contact forces.
- Miniature mechanisms for planetary robotics applications such as rovers and sub-surface explorers. Novel mechanisms are needed to enable exploration of planetary bodies by low-power, low-weight robotic systems. Examples include rock fracture devices, sample manipulation and caching devices, instrument placement devices, sub-surface sampling devices, and the actuation components for these devices.
- Low-mass and low-power surface and sub-surface sampling devices (e.g., scraping, drilling, impact or vibratory surface penetration) for planetary surface exploration.
- Miniature, low-power, low-weight mechanisms are needed to enable planetary exploration and science by rovers, sub-surface explorers, aerobots, and underwater robots.

Human/Robotic Interface
Proposals that improve operator efficiency via advanced displays, controls and telepresence interfaces, improve ground based robotic control technology, and improve the ability of humans and computers to seamlessly control robotic systems are sought. Specific technology requirements include the following:
- Tactile feedback devices that provide operator awareness of contact between work space objects and the robot structure. Key aspects of this technology are ergonomics and safety.
- Force feedback devices that provide operator awareness of manipulator and payload inertia, gripping force, and forces and moments due to contact with external objects. Key aspects of this technology are ergonomics and safety.
- Stereo graphic display systems that provide high fidelity depth perception, field of view, and high resolution.
- Ground-based control technology which is able to compensate for time delays of several seconds.
- User interface that does not require the operator to wear exoskeletons to control the motions of the robot.

- Tracking position and orientation of user appendages, (i.e., head, arms, fingers, eyes) for the purpose of providing motion commands to the robot. Key aspects of this technology are to free the operator of any exoskeletons or devices attached to the body that impede or restrict operator movements.
- Adaptive fault tolerant software: Systems capable of dynamic reconfiguration and learning.
- Intelligent autonomous systems: Artificial intelligence based systems and architectures, with provision for crew oversight.

09.10 Advanced Manufacturing and Nanotechnology
Lead Center: JSC

Proposals are sought to establish and maintain state-of-the-art manufacturing, hardware production, manufacturing processes, and application of nanotechnology as they relate to future spacecraft. Proposals in the following areas should be focused on hardware or software products.

Manufacturing Technology:
Improve rapid prototyping using the Stereolithography (SLA) and Fusion Deposition Modeling (FDM) techniques to produce functional prototypes and working models, including use of single wall nanotubes. Improve composites manufacturing using fiber placement, filament winding, laminations, pultrusion, and resin transfer molding (RTM) techniques. Improve the manufacture and precision of miniature mechanical components and electronic assemblies, and develop micro- and nanotechnologies to manufacture components.

Nanotechnology:
Potential applications and manufacturing techniques of single walled carbon nanotubes (SWNT), or "Buckey tubes". Applications include structural reinforcement, electronic, magnetic, lubricating, and optical devices.

Non-Metallics Manufacturing:
Improve non-metallic manufacturing and fabrication using a wide range of materials. Complete electronic fabrication and assembly, and printed circuit board fabrication. Improve metal finishing of aerospace components on metallic and nonmetallic surfaces and on ferrous and non-ferrous alloys.

Machine Tool Programming:
Lessen the time necessary to program computer numerical control (CNC) machinery using computer-aided design/computer-aided manufacturing (CAD/CAM) programs. Machine tool operations of interest include multi-axis milling, turning, electrical discharge machining (EDM), wire electrical discharge machining (WEDM), and surface and cylindrical grinding.

Sheet Metal and Welding:
Improve the use of state-of-the-art equipment for programmable equipment. Improve welding techniques using processes that involve ferrous and nonferrous alloys, including shielded arc, gas metal arc, oxy-fuel, gas tungsten arc, plasma, ultrasonic, friction-stir, resistance spot and seam, laser and other emerging technologies.

Manufacturing Process Development:
Improve the efficiency of space flight hardware production through the development of new processes, advanced technology, and concurrent engineering. Of special interest are advanced flexible manufacturing systems where each part can have more than one process plan and can be performed on alternate machines or simultaneously deal with alternate routing options, and virtual manufacturing systems that include the development of qualitative and quantitative procedures.

10 Achieve Routine Space Travel

NASA’s Human Space Flight Program seeks to open the space frontier by exploring, using and enabling its development, and to expand the human experience into the far reaches of space through the attainment of safe, reliable, low-cost transportation. NASA seeks technologies to support the development of sensors and instrumentation systems, including ecological, environmental, and weather measurement technologies, for use in ground processing, launch, and landing of space vehicles and payloads. NASA seeks innovative technologies to prevent, detect, and retard corrosion of ground processing equipment and facilities. NASA also seeks innovative industrial engineering concepts, methodologies, and processes that will enable a more cost-effective and efficient hardware processing schedule.

10.01 Advanced Corrosion Technology
Lead Center: KSC

Advanced technologies are solicited to prevent, detect, retard, or control corrosion on systems such as ground support equipment or facility infrastructure to improve the safety, reliability, and reduce maintenance costs associated with the exposure to the extremely corrosive launch environment at the Kennedy Space Center. New and innovative techniques derived from technologies such as electrochemistry, protective coatings, cathodic protection, chemical treatments, and inhibitors could be used to enhance the corrosion control effort for all affected systems. The launch environment at KSC significantly contributes to the degradation of hazardous fluid and high pressure gas systems, potable water distribution piping, steel reinforced concrete structures, steel and aluminum access structures, and all types of ground support equipment. Technologies developed in this area are easily transferred to the commercial community and are considered excellent dual use candidates. Corrosion technology is an area of great potential growth based on the magnitude of problems in the transportation and infrastructure industry. Specific areas of interest include:

- Real time salt and rainwater pH sensors for seacoast environment monitoring
- Techniques to arrest corrosion of embedded reinforcing steel in concrete
- Production of seamless tubing from corrosion resistant alloys

10.02 Environmental and Ecological Technologies
Lead Center: KSC

Proposals are solicited for innovative and commercially viable technologies in environmental management, environmental and ecological monitoring, life sciences flight payloads and laboratory functions. Innovative technologies are needed that will improve the capability to collect and analyze environmental and ecological data. Of particular emphasis are the development of systems to monitor ecological parameters, biological organisms and environmental conditions remotely over long periods of time under field and controlled chamber conditions. Improved sensors for surface and ground water, ambient air, plant growth chambers, animal holding rooms, bioreactors, and incubators are needed. For sensors, miniaturization and automation should be emphasized along with reliability and minimal calibration requirements. Techniques to significantly improve and automate data management capabilities are required, especially those that incorporate geographical information system technologies for environmental and ecological monitoring and selected growth chamber data which lend themselves to spatial dependent manipulations. Innovative remediation technologies are also important, particularly methods that minimize the impact to surrounding lands and facilities. Methodologies to minimize or prevent the generation of pollution during operations are also emphasized. Specific areas of emphasis are:

- Expert data and information management systems for improving environmental management and control including those with GIS capabilities.
- Laboratory and field measurement devices including miniaturization of devices used in environmental monitoring, control and remediation.
- Sensors for environmental parameters and microbial organisms, including remote sensors.
- Remediation of chemical and petroleum soil and ground water contamination including in-situ methods and portable systems.
- Expert control systems for environmental chambers.
- Tools to identify the soil characteristics of a contaminated site, e.g., conductivity, transmissivity, and electrical differential.
- Pollution preventing refrigerants, coatings, and non-ozone depleting cleaning substitutes.
- Control technologies for volatile organic compounds (including those generated during painting operations and operation of power generators) and toxic and hazardous air pollutants (including nitrogen tetroxide, hydrazine and monomethylhydrazine).
- Control technologies for cost effective waste minimization and/or reuse of industrial wastewater and hypergol waste.

10.03 Launch and Landing Site Instrumentation and Meterological Technologies
Lead Center: KSC

This subtopic focuses on the development of sensors, transducers, instrumentation systems and meteorological technologies uniquely suited to and used for ground processing, launch, and landing of space vehicles and payloads. This includes detection of hazardous gases, hydrogen leaks, fires, and toxic vapors; transducers for cryogenic and hypergolic servicing systems, data acquisition, and controls; optical and acoustic sensors and systems; field inspection and testing; contamination monitoring for payload processing; landing aids; weather and environmental sensors for ground processing, launch, and landing operations; and advanced sensors for automated ground operations including automated surface and structural inspection, remote sensing, and real-time vision systems for automated control and monitoring of ground processing. Areas in which innovations are sought include:

- Advanced Hazardous Gas Detection Technology. Planned usage is realtime multigas detection around space vehicle propellant systems during propellant loading, ground test firings, prelaunch checkout, launch and ascent (up to approximately 18 g rms shock and vibration).
- Small, inexpensive, lightweight, rugged mass spectrometer capable of reliably measuring at least from 1 ppm to 100,000 ppm hydrogen, helium, oxygen and argon in a nitrogen background, and from 1 ppm to 100,000 ppm hydrogen, nitrogen, oxygen, and argon in a helium background, during test firings, prelaunch checkout, launch and ascent (up to approximately 18 g rms shock and vibration).
- Small, lightweight, rugged high vacuum pump for mass spectrometer system, capable of 60 liter/second or greater throughput, requiring no cryogenic fluids or inputs other than electrical power, and capable of operation without external roughing or backing pumps, during test firings, prelaunch checkout, launch and ascent (up to approximately 18 g rms shock and vibration).
- Small, lightweight, rugged sample delivery system capable of delivering samples at ambient pressures ranging from 1 atmosphere down to approximately 100 Torr from multiple points within a space vehicle through sample tubing to a mass spectrometer analyzer at regulated inlet pressure. Gases are as specified above. System attributes include rapid sample transport, low swept volume upstream of the analyzer inlet and sufficient health checks to verify proper operation, during test firings, prelaunch checkout, launch and ascent (up to approximately 18 g rms shock and vibration).
- The threat of adverse weather is a major cause of delay to launch, landing and ground operations. Lightning triggered by launch vehicles as they ascend is of special concern because current technology is inadequate to observe the conditions conducive to triggered lightning. An operationally viable real-time method is required to measure the spatial distribution of the intensity of electric fields in and around clouds in the vicinity of the launch site near the time of launch. Techniques such as rocket probes or non-eyesafe LIDARs which pose potential risks to personnel or equipment are not operationally viable. Remote sensing techniques are strongly preferred. High reliability, high probability of detection and low false alarm rate are essential. Cost is a significant consideration. Techniques relying exclusively on surface field mill or conventional radar observations are known to be inadequate. Techniques such as dual-polarization radar which rely on the presence of ice in the clouds are of severely limited value since electric fields in warm clouds and in clear air near clouds are also sought, but a reliable method of assuring that a detached thunderstorm anvil is charge-free would be of significant benefit.
- Portable, direct-reading sensors and area monitors for hydrazine and monomethyl hydrazine capable of measuring at least 1 to 1000 ppb in air with normal ambient humidity range, with 15-30 seconds to achieve 90% of final reading, 15 minute or less warmup, accurate to the greater error of +/- 2 ppb or 10% of reading, and operating 3-6 months without calibration and maintenance.
- Small rugged O2 sensor for leak detection on rocket engines. Range of at least 250 ppm to 250,000 ppm with accuracy equal or greater than plus or minus 5% of reading. The sensor must be capable of operation from approximately 32 to 130 degrees F and survive approximately -224 to +175 degrees F. Response time should be 10 seconds or less to indicate 90% of a change in concentration. The sensor should not be capable of causing a hazard, contamination, or corrosion when used on or around rocket engines during ground or flight testing.

- Benchtop size pressure transducer dynamic calibration system capable of exciting pressure transducers with either shock or sinusoidal pressure variations from at least 0.1 to 1.0 psi, selectable (170 dB), and from at least 1 to 5000 Hz frequency range. Traceability to NIST primary standards is required via combination of reference transducers, basic physical measurements, and calculation with supporting engineering error analysis.
- Small, inexpensive camera or sensor capable of imaging and uniquely identifying hydrogen and hydrazine fires. Resolution should be at least 160 x 120 pixels or equivalent, higher resolution is preferred. The camera or sensor should be capable of seeing a six inch or smaller hydrogen flame at least 50 feet against a blue sky background, and must be rugged to withstand shock and vibrations induced by nearby liftoff of Space Shuttle or similar launch vehicle.
- Small, rugged hydrogen leak detection sensors capable of measuring at least 100-100,000 ppm in air, nitrogen, or helium backgrounds. The sensor must respond to 90% of a change in concentration in 15-30 seconds. The sensor must also be impervious to changes in oxygen concentration, ambient temperature, humidity, and other environmental factors.
- Portable, reliable, and easily operated innovative field inspection sensors or systems capable of detecting and measuring flaws on flight hardware including debonds of insulation, structural cracks, surface defects, and corrosion.
- Portable, reliable, and easily operated innovative field instruments to test aerospace fastener functionality, such as bolt preload, cracks under rivet heads, and weld seam integrity, without requiring hazardous field operations.
- Point sensors for hydrazine, monomethyl hydrazine, and nitrogen dioxide capable of measuring at least from 1 to 100 ppm in 15 seconds or less with small size (0.007 cubic meters or less) at the leak or sample location and operating 3-6 months without calibration and maintenance, during test firings, prelaunch checkout, launch and ascent (up to approximately 18 g rms shock and vibration).

10.04 Operations Industrial Engineering
Lead Center: KSC

Kennedy Space Center (KSC) operations have many unique aspects which require development of innovative industrial engineering (IE) technologies in order to obtain the substantial benefits derived from applying IE principles in other organizations. Operations IE is a technical discipline devoted to the science of process improvement and optimization of operational phases of complex systems. The Space Shuttle is NASA’s first major program with a long-term operational phase. All major current and potential future human space flight programs (the International Space Station, X-vehicles, and Mars missions) are also projected to have lengthy operational phases. Payload processing activities are also emphasizing repeatable processes and improved customer satisfaction. Therefore, operations IE technologies are becoming even more strategically important to NASA. Operations IE proposals should address the generic challenges of “doing more with less” and delivering safer, better, faster, and cheaper products. Advanced tools for improving/managing processes and performance measurement systems are needed for spacecraft processing at KSC. Proposals should also identify potential applications for enhancing the operational phases of new NASA programs. Proposals may address the development of new concepts, methodologies, processes, and/or software support systems which advance the state-of-the-art in one or any combination of the following general areas of interest: operations research, process simulation modeling, statistical process control, experimental design, planning and scheduling systems, project management risk analysis, cost-benefit analysis, methods analysis, work measurement, human factors, ergonomics, facility layout/design, incident analysis, performance metrics, management information systems, and benchmarking. Specific interests for the 1998 solicitation include (but are not limited to) those listed below:

- Advanced decision analysis, human factors, and operations research tools for optimizing utilization of scarce resources and minimizing the potential for human error during human missions to Mars and aircraft/reusable spacecraft (Shuttle and X-33) maintenance activities.
- Advanced statistical quality control techniques for ensuring high quality, affordable manufacturing and processing of unique space hardware supporting human exploration and development of space.
- Tools to facilitate a project management approach to large-scale transition and change in technical organizations. The tools should incorporate a set of best practices for successfully designing, implementing,

and managing desired changes. The tools should also support strategic planning efforts through development, deployment, and refinement of goals, objectives, and organizational alignment measures.
- Structured approaches for relating process-level and organization-level metrics.
- A system that assists organizations in assessing risks associated with different proposed organizational approaches as they organize to most effectively meet changing needs. The changes may include personnel levels, roles, responsibilities, relationships, products, and skills.
- A tool for rapidly assessing cost, schedule, and technical risks of proposed Shuttle hardware and software upgrades.
- A tool for optimizing facility layouts for flight hardware, ground support equipment, and support functions. The tool should include an expert system capability to assist in multi-flow assessment planning and account for random unplanned activities and varying requirements.
- Advanced data analysis, mining, and warehousing tools to assist in the development and maintenance of metrics supporting performance-based contracting and process improvement activities.
- Innovative methods for human factors training and evaluation of training effectiveness.
- Advanced task/methods analysis and procedure design techniques to enable effective implementation of advanced software and hardware systems in spacecraft test and checkout operations. Techniques should maximize work place safety and minimize the potential for human errors.
- Advanced tools to measure and improve human-computer interaction with consoles and portable data collection devices.
- Advanced technology to facilitate group work and distributed decision-making.

11 Enrich Life On Earth Through People Living and Working in Space

By its nature, the exploration and development of Space expands our knowledge and fosters technologies that have great potential benefit on Earth. The HEDS enterprise will be alert to and communicate the early medical, educational, economic, and social benefits from its programs. The objectives of this topic include promoting knowledge and technologies that promise to enhance our health and quality of life; broadening and strengthen our nation's achievements in science, math, and engineering; involve our nation's citizens in the adventure of exploring space; and joining other nations in the international exploration and settlement of space.

11.01 Commercial Microgravity Research
Lead Center: MSFC

In accordance with the Space Act, as amended, to "Seek and encourage to the maximum extent possible the fullest commercial use of space," NASA facilitates the use of space for commercial products and services. The products may utilize information from in-space activities to enhance an Earth-based effort, or may require in-space manufacturing. This subtopic has the goal of commercial demonstration of pivotal technologies or processes and the transfer of these technologies to industry in space or on earth. Automated processes and hardware that will reduce crew time are a priority.

This subtopic, therefore, has two goals. First, the commercial demonstration of pivotal technologies or processes, second, the development of associated infrastructure equipment for commercial experimentation and operations in space, or the transfer of these technologies to industry in space or on Earth. Automated processes and hardware (robotics) which will reduce crew time are a priority. All agency activity in microgravity including those in life science and microgravity sciences which lead to commercial products and services are of interest. Some specific areas for which proposals are sought include:

Cell System Biotechnology
Instrumentation to analyze cell reactor systems and characterize cell structure in micro-gravity in order to develop enhanced drug therapies that can also be applied to pharmaceutical development and commercialization.

Biomedical and Agricultural

Instrumentation or techniques that exploit space-derived capabilities or data to support the commercial development of space by the agricultural, medical or pharmaceutical industry. This includes, in particular:

- Innovative techniques for dynamic control and cryogenic preservation of protein crystals.
- Innovations in preparation of protein crystals for x-ray diffraction experiments without the use of frangible materials.

- Physiological measurement in micro-g of bone growth and immune system in micro-g.
- Agricultural research, i.e., genetic engineering of plants using micro-g.
- Innovative research in plant derived pharmaceuticals using micro-g.

Materials Science

- Applications using space-grown semiconductor crystals including epitaxilly grown materials for commercial electronic devices. The applications will also attempt to use the knowledge of the space grown material behavior to enhance ground processing of the materials to achieve equivalent performance of space-grown materials in electronic circuitry.
- Applications using space-grown optical electronic materials such as fluoride glasses and non-linear optical compounds for commercial optical electronic devices and to achieve equivalent performance of space grown materials in ground processing.
- Innovations using non-linear optical material to be processed in space.
- Innovations for new space-processed glasses for optical electronic applications.

Microgravity Payloads
Design/develop microgravity payloads for space station applications that lead to commercial products or services. Enabling commercial technologies that promote the human exploration and development of space.

Combustion Science
Innovative applications in combustion research that will lead to developing commercial products or improved processes through the unique properties of space or through enhanced or innovative techniques on the ground.

Food Technology
Innovative applications of space research in food technology that will lead to developing commercial food products or improved food processes through the unique properties of space or through enhanced or innovative techniques on the ground.

11.02 Telemedicine and Health Diagnostic Services and Communications
Lead Center: JSC

Telemedicine, the integration of telecommunications, computer, and medical technologies, permits NASA to monitor the physiological and medical impact of space flight on astronauts. Innovative technologies are being sought to support the current flight programs, such as Space Shuttle, International Space Station and possible tools for support of Space exploration programs of the future. During the past four decades, NASA telemedicine technologies have found many applications in the delivery of health care on Earth. Innovations in the following technologies and applications (including hardware and software) in telemedicine are being sought:

- Dynamic imaging **-** (Full-motion, high-resolution images incorporating audio.) Dynamic imaging may be divided into interactive televideo (IATV), with parties at both ends communicating in real time (e.g., patient-physician consultations, interactive continuing education), and store-and-forward, with video and audio clips transmitted for review at a later time, in the equivalent of audio-video e-mail (e.g., physician-physician consultations that are not dependent of immediate review, audio-video clips retrieved for tele-education).
- Static imaging-single-frame visual images, typically of much higher resolution than is required for IATV consultations (which are generally of a resolution similar to a commercial TV picture). Examples include

teleradiology, telepathology, and teledermatology. Although configured as a store-and-forward technology, static imaging may also be done in real time.
- Biomedical monitoring and sensing - involves the acquisition, processing, communication, and display of electrical, physical, or chemical aspects of a human's health or physiologic state. This mode of telemedicine may be used for real time monitoring or for store-and-forward applications.

The resolution, motion-handling, and interactivity of the telemedicine modalities are quite different, the hardware, software, and transmission requirements for these modalities are likewise very different. Information indexing and retrieval and the management of large databases are essential components of telemedicine. The following hardware and software technologies are of particular interest.

Hardware:
- Integrated transportable computerized medical systems capable of medical data acquisition, storage, retrieval and communication for use in environments with little or no medical facilities and expertise.
- Data compression systems.
- Wireless communication systems.
- Intelligent sensor communication and interpretation systems.
- Advanced human/computer interface systems.

Software:
- Data mining technology.
- Data compression technology.
- Decision support technology.
- Data security technology.
- Wireless communication technology.
- Intelligent sensor distributed data communication and Interpretation technology.
- Advanced human/computer interface technology.

11.03 Technological Methods for Enhancing Public Understanding/Involvement of Science/Technology Programs
Lead Center: MSFC

The future of Human Exploration and Development of Space (HEDS) is heavily reliant on NASA customer engagement. Public access to HEDS programs and HEDS understanding of customer expectations must be integrated into a seamless information exchange and information processing and decision system allowing HEDS managers to respond promptly to customer expectations through program modification and/or new program development.

Educational Outreach--Within the commercial research and development program, there needs to be an educational outreach plan that links commercial research centers, academia, and industry to bring the achievements of commercial space development (new drugs, materials such as special tooling, agricultural products, etc.) into the classroom. The educational outreach will be "tiered" to target specific levels of education: primary, secondary, and college students through post-doctoral research.

Proposals may address the development of new concepts, methodologies, technologies, processes, software support systems and/or training systems which advance the state of the art in techniques to improve distribution and feedback for information about NASA programs, strategic planning and knowledge derived from space based activities. Included are the following:

Information Distribution and Exchange:
- Technologies to distribute NASA information and data in an entertaining, educational and user friendly manner.

- Technologies to improve the accessibility of NASA and NASA program Internet homepages and tools to visually coordinate and systematically integrate related subpages and other information distribution systems.
- Technologies to improve customer feedback and involvement in NASA planning activities and to encourage direct customer participation in NASA activities. · Virtual tour (reality) technology for educating the public about NASA programs. Customer Analysis and Modeling:
- Technologies to improve decision making through modeling and analyzing complex and conflicting customer needs and desires.
- Technologies to assist optimization modeling and statistical analysis for "best outcome" program structuring and restructuring.
- Metrics technologies for continual program evaluation and real-time response of program impact to NASA customers. Training:
- Innovative software support technologies enabling familiarization and awareness-level training of NASA programs for NASA employees and other outreach volunteers.

Technologies to promote NASA in the K-12 schools that are portable and easy to use that do not rely on the schools for any assisting hardware (e.g., overhead projectors should not be needed as a separate piece of hardware). Innovative technologies that promote math and science that would appeal to all children (including girls and minorities) using space scenarios as the backdrop.

12 Advance Space Communications and Operations

For frequent, affordable, capable space missions in the 21st century, key technologies that contribute to lowering life-cycle costs and increasing scientific returns are required. This includes technologies, concepts, and advanced techniques for reliable telecommunication services, microelectronics, flight computing, autonomous spacecraft guidance, navigation, tracking and control, 'intelligent' and automated ground and flight systems, data transfer, handling and storage, high-speed data communications networks. For NASA’s use of commercial services, advanced techniques and products that support commercial LEO/MEO/GEO satellite networks are needed.

12.01 Flight/Ground System Autonomous Operations
Lead Center: JSC

Development of spacecraft with a high degree of on-board autonomy, possessing autonomous navigation and control, self-monitoring, and smart instruments will enhance the efficiency of upcoming NASA flights. The challenges include selective migration of operations functions to the spacecraft, new onboard software architecture and operating system concepts to integrate these functions, and new software design. NASA seeks innovations that demonstrate the following characteristics: spacecraft and instruments appearing as nodes on a network; similar ground and flight operating systems; spacecraft interfaces that appear the same to ground support systems; system operations requiring minimal hands-on effort; centralized anomaly resolution; and direct delivery of science data to users. In the area of on-board autonomy, areas of interest include:

- Guidance, navigation, and control.
- Planning, scheduling, and resource management.
- Onboard data management.
- Fault detection and recovery.
- Onboard software architectures and operating systems.
- Design, testing, and validation tools.

Innovations should use commercial standards for development, off-the-shelf hardware and software when possible, and have a high degree of commercialization potential.

Areas of interest include:
- Multimedia for access and control of all mission-specific data and processes.

- Direct access to and control of instruments and their returned data by the investigators.
- Distributed intelligent agents for automation of spacecraft and ground operations functions.
- Advanced applications of expert system, model-based, and agent-based technologies in mission-operations automation.
- Internet-based and Java-based approaches to mission operations.
- Advanced data and information visualization techniques for mission.
- Reuse of mission operations software on NT platforms in addition to UNIX.
- Flexible plug and play architecture and standards.
- Plug and play commercial software components that execute operations functions.
- Techniques and tools for incorporating legacy applications into plug and play architectures.
- Techniques for electronic documentation, electronic process control, massive distributed databases, intelligent archiving and retrieval, data analysis and visualization and other advanced information technologies.
- Innovations for greater capacity high-speed data communication networks that are the result of increased data transfer and storage requirements.

8.3 EARTH SCIENCE

NASA's Earth Science Enterprise uses satellites and other tools to intensively study the Earth in an effort to expand our understanding of how natural processes affect us, and how we might be affecting them. Such studies will yield improved weather forecasts, tools for managing agriculture and forests, information for fishermen and local planners, and, eventually, the ability to predict how the climate will change in the future. Earth Science has three main components: a series of Earth-observing satellites, an advanced data system, and teams of scientists who will study the data. Key areas of study include clouds; water and energy cycles; oceans; the chemistry of the atmosphere; land surface; water and ecosystem processes; glaciers and polar ice sheets; and the solid Earth. Working together with the nations of the world, Earth Science seeks to improve our knowledge of the Earth and to use that knowledge to the benefit of all humanity.

http://www.hq.nasa.gov/office/mtpe/

13 Earth Measurement Systems

NASA is fostering innovations that support implementation of the Earth Science (ES) program. ES is an integrated international enterprise to study the Earth system. ES uses the unique perspective available from orbit to study land cover and land use changes, short and long term climate variability, natural hazards, and environmental changes. Additionally, ES uses in-situ and airborne measurements to complement those acquired from Earth orbit. The largest ground and data system ever undertaken will provide the facility for command and control of flight segments and for processing, distribution, storage, and archival of vast amounts of data.

13.01 Lidar Systems for Ranging and Altimetry
Lead Center: GSFC

Major subsystem improvements are needed for airborne and space-based laser altimeter sensors of planetary surface topography, vegetation, clouds, and aerosols; and also for low signal level, ground-based satellite laser ranging systems that measure laser pulse time-of-flight to either cooperative reflectors or laser transponders on satellites. Innovations are required in laser sensor subsystems as well as in the overall efficiency, compactness, and reliability of the sensor with the goal of developing a new generation of instrumentation for low-cost, flight missions and autonomous operation. Specific technology challenges include the following:

- Pulsed Nd:YAG laser oscillators based on aluminum-free diode-pumping with greater than or equal to 6% overall electrical-to-optical efficiency and greater than 10 mJoule pulse energy for space-based laser altimeter missions.
- Compact, conductively-cooled near-infrared laser transmitters with < 5 nsec pulses, single spatial mode, several mjoule performance at kHz pulse rates.

- Diode-pumped, Q-switched neodymium-based microlaser/amplifier systems operating reliably at few kHz rates with frequency-doubled pulsewidth less than or equal to 150 psec & 200 mW power at 532 nm.
- Quadrant Geiger-mode avalanche, photo diodes or comparable microchannel plate photomultipliers with a quantum efficiency approaching 40% @ 532 nm, less than or equal to 400 psec risetime, and submicrosecond gating at 2 kHz rates.
- Large aperture, ultralight-weight, scanning lidar receivers with high efficiency, narrow field-of-view, & narrowband filtering.
- Silicon avalanche photo diodes, photodiode arrays, and photon counting detectors with quantum efficiency greater than 35% at 1064 nm wavelength; and high efficiency, high speed, & low noise detectors for the 1500 to 2200 nm wavelength region.
- Adaptive photon-counting correlation range receivers capable of extracting satellite range data with high time resolution (< 20 psec) during daylight operations.
- High detectivity, spectrally diverse receivers including narrowband notch filters, high transmission narrow bandpass optical filters, & multi-channel array detection.
- Optical devices for high spectral resolution measurements of Fabry-Perot interferometer output, specifically diffractive optic technologies.
- Broadly-tunable narrowband laser sources throughout the visible to mid-IR region for incorporation into compact, lightweight species measuring instrumentation.

13.02 Remote Sensing Technology for Coastal Research
Lead Center: SSC

The coastal region is comprised of ecosystems marked by frequent change and widely fluctuating transitional boundaries of land and water. Remote sensing technology is needed to better identify and delineate important coastal environmental phenomena and to characterize their temporal and spatial dynamics. This includes imaging in the solar reflected spectral region over a range of temporal and spatial scales. Emerging applications will study the complexity and dynamics of the zone extending several kilometers seaward or inland of the shoreline. Significant remote sensing technologies exist currently that have the ability to characterize:

- Both surface and subsurface water variables (e.g., temperature, salinity, suspended materials) and their changes with depth.
- Vegetation changes occurring on small spatial scales or for which the spectral response is influenced by changing water level.
- Natural hazards (e.g., hurricanes, sea level rise) and man-induced pressures on land cover and land use change in near shore areas.
- Subsurface soil and sediment properties and their changes with depth in environments covered by vegetation or water.

Efforts to integrate multiple sensors and/or supporting instrumentation are needed. Specific technological areas of focus include the following:

High Spatial Resolution, Hyperspectral/Thermal Airborne and Ground-Based Sensor Technology:
- Broad emphasis on imagery of dry land and wetland vegetation, and water targets within the incident solar (ca. 400-2,500 nm) and emitted thermal (8-14 mm) spectra.
- Ground pixel resolution of 1 square meter or better while maintaining a scan swath width of 0.5 km or more for airborne systems.
- Image resolution of 640 by 512 pixels or better for ground-based instruments.
- Hyperspectral bands of: 10 nm or better spectral resolution to span the 400 nm-NIR range; 20 nm or better resolution to span the NIR-2,500 nm range.
- One or more bands in the 8-14 mm range.
- Co-registration of all channels in a data cube that contains GPS coordinates for target location.
- Channel selectivity based on application.
- Radiometric calibration for each channel.

High Resolution, Low Frequency, Subsurface-Penetrating Sensor Technology:

- Emphasis on measurement for a stratified depth profile in soils, peatlands, wetlands, and shallow marine environments.
- Examples of variables of interest for characterization: organic/mineral sediment type; inundation/wetness condition; presence of archeological and other anomalies (e.g., mineral deposits, pipelines); physicochemical water properties (e.g., salinity, dissolved compounds/pollutants).
- Low frequency range (100 Hz - 500 MHz).
- Spatial resolution: vertical <2m; lateral <10m.
- Depth penetration: desired range of 1m minimum - 30m maximum (including water depth).
- Incorporate capability for good geopositioning.
- Desirable to incorporate innovative, independent technologies to measure variables (e.g., temperature) for improved inversion data analyses.

Moderate Resolution Hyperspectral Sensor Technology from Earth Orbit:

- Spectral sampling at 10nm bandwidth over 0.4-2.5 mm with high signal to noise ratio over 5-80% albedo.
- Spatial resolution and coverage of ~30km swath at 30m GSD from ~490km altitude.
- Emphasis on spectral and radiometric calibration and spatial/spectral co-registration of the data cube to enable advanced surface retrievals and compensation of atmospheric/scattering effects.
- Demonstrations of interest include: size/mass reductions in integrated camera/spectrometer systems utilizing modular architectures, high read rate VIS/NIR and SWIR focal planes with reduced power/cooling needs, integrated sensor system electronics, on-board processing and data reduction tailored to data type and application.

13.03 Lidar Systems for Atmospheric Measurements
Lead Center: LaRC

Innovative developments are needed in lidar technology for the remote measurement of atmospheric aerosols, clouds, molecular species (ozone, water vapor, carbon monoxide, methane, and nitrous oxide) and meteorological parameters (density, pressure, temperature, and wind profiles). Specifically, technologies for expanding the measurement capabilities of current airborne lidar systems and for the next generation of spaceborne and Unmanned Aeronautical Vehicle (UAV) lidar systems are sought. Technology innovations may include lidar components, subsystems, and complete systems and may address reduced weight or power or increased energy efficiency, reliability, or autonomous operation.

For atmospheric constituent measurements:

- Solid-state laser technology for tunable and/or fixed frequency, high-energy (>500 mJ at more than 10 Hz) pulsed lasers for spaceborne applications. This includes solid-state laser materials compatible with diode pumping and high efficiency (>2.5% wallplug) and new or improved optical materials for high efficiency frequency conversion. Of prime interest are long-lifetime, low weight and volume materials and technologies applicable to lasers operating in the 0.28-0.32, 0.47-0.54, 0.7-1.1, and 1.5-2.4 micron regions; also interested in the 3.2-4.7 micron region. Also needed are single-mode, line-narrowed, compact sources for injection seeding in the 0.7-1.1 and 0.28-0.32 micron regions and high reliability, high efficiency, conductively cooled diode arrays operating in wavelength regions for pumping solid-state lasers.
- Lidar receiver technology for large (> 3m2), lightweight collection apertures having multiple-wavelength operation from UV to near IR are needed. Inherent spectral selection/dispersion and high peak transmission (50-80 %), electromagnetically tuned, narrow bandwidth (10-100 picometers) filtering are desirable. Small- and large-angle scanning (up to 3 degrees and 30-60 degrees off nadir, respectively) of 0.5-meter and 1.0-meter lidar systems are needed for space. Low mass and few to no moving parts.
- Signal detection and processing subsystems with quick recovery (less than 3 microseconds) from saturation and high-speed, high-quantum efficiency (30-80 %) detectors with low-noise and good linearity are needed for lidar operation over large dynamic ranges.

- For UAV applications, compact, high repetition rate, narrow linewidth laser transmitter systems are needed that produce energies from micro- to milliJoules (30 to 50 mJ) per pulse. Laser energies of more than 100 mJ at 30-1000 Hz in the UV and more than 200 mJ at 10-20 Hz in the 355, 940, and 1064 nm region are needed.

For coherent wind measurements:

- Low mass, compact optics for deflecting a circularly polarized laser beam for a conical scan. Diameters of 5 cm to 2 m with an immediate need of up to 50 cm. Preservation of laser beam quality is required.
- Technology for autonomous operation and alignment maintenance of coherent lidar systems.
- Fast (few tens of microseconds) lag-angle compensation optics technology for precise, reliable steering of the optical axis of a space-based Doppler lidar.
- Single-element and array detectors having high bandwidth, high quantum efficiencies over the entire bandwidth, linearity, and minimum cooling requirements. Also, an optical detector combined with a preamplifier in a single integrated circuit, with combined bandwidth up to several GHz.
- Diode-laser arrays operating near .79 micrometers having pulse lengths >1.0 ms, energy densities >1.3 J/cm2, duty cycle > .02, and narrow beam divergence.
- High efficiency methods for concentrating the emissions from nominal 1.0 cm square arrays to 4.0 mm diameter spot sizes.
- Tunable single-mode semiconductor lasers or other compact, single frequency sources for use as injection seeders and/or local oscillators, with linewidths 0.1-0.2 MHz operating in the 1.8-2.2 micron and 3.0-3.5 micron regions.
- 780- or 850-nm external grating lasers coupled into PM fiber and capable of delivering 10mW into the fiber. These products should be fiber coupled (input and output) tapered amlifiers (MOPA) at 780- or 850- nm. Should capable of >200mW into PM fiber and should be compact/lightweight.

For direct detection wind measurements:

- Techniques, components, and systems for measurement of the wind field and wind shear in the lower atmosphere using direct-detection, with accuracy better than 1 meter/second and range resolution better than 50 meters. Eye safety is a consideration.
- Technology for high quantum efficiency (>10 %), low dark count (<1000 counts/second) photon counting detectors at 1064 nanometers that should be compatible with long term operation in space environment.
- Single mode, diode pumped, pulsed, solid state laser at 355, 946, and 1064 nanometers with a narrow spectral width <30 MHz at 1064 nanometers. High wall plug efficiency, passive cooling, compact, rugged design, and 10 watt average for multi-year satellite missions.
- High spectral resolution filters for direct detection of winds at 355 and 1064 nanometers. The filter to have a 100 MHz bandwidth (FWHM) at 1064 nanometers, and a 1 GHz bandwidth (FWHM) at 355 nanometers. Also, high throughput, out of band spectral blocking, frequency tunable, and frequency stabilization that should be compatible with long term operation in space environment.

13.04 Airborne Stratospheric and Ecosystem Science Instruments

Lead Center: ARC

NASA requires innovations in methods for making measurements from stratospheric airborne platforms (both conventional and remotely piloted), and new methods in data analyses and model development. Measurements of interest include both remote and *in situ* measurements of the stratosphere, as well as, the surface of the Earth from stratospheric platform aircraft such as the NASA ER-2 and unmanned aeronautical vehicles (UAVs). Stratospheric composition measurements include the identity and concentration of gaseous species, the number, size, shape and composition distributions of cloud and aerosol particles, and radiative properties and fields. Remote measurements for the biosphere include species, community and land use identities, biophysical and biochemical characteristics, and biodiversity measures of ecosystems on land and in water, and their relationship to geophysical variables. Field instrumentation is needed to correlate the airborne measurements with exchange of biogenic trace gases between the biosphere and the atmosphere. These measurements are critical to NASA and also have many commercial applications such as water and land usage for city planning and agribusiness, resource management, disease monitoring, ecosystem remediation and natural disaster (earthquake, fires and floods) assessment. Innovations needed include:

- Advanced platforms, instrumentation and technology with increased speed, sensitivity, accuracy, specificity, and space-time coverage for the investigation of both physical and chemical stratospheric phenomena.
- Advanced detector, source, pointing/tracking and miniaturization technology as well as improved sensor survival for long periods in harsh environments.
- Self-diagnosis techniques that provide a continuous measure of data quality and instrument health. Real-time adjustments in sensor operation to compensate for instrument degradation or changes in sensed properties.
- Data processing techniques that increase the usefulness of raw data in answering specific questions of current concern.
- Analysis and modeling of the chemistry and dynamics of species measured from the ER-2 and future very high altitude science platform aircraft.
- Improvements and applications of Digital Array Scanned Interferometry and innovative miniaturized CCD cameras for ecosystem, aquatic, atmospheric and edaphic analyses from laboratory, to field, to airborne, then to space.
- Innovative uses of laser and other high speed/repeat cycle instrumentation for measurement of architectural properties of plant canopies and field measurement of biogenic trace gas fluxes of a variety of gas species, including CO2, N2O, NO, etc.
- Technology to improve the real time acquisition of data about disaster assessment problems, including thermal scanners that can quantitatively measure high wildfire temperatures, can downlink or uplink these data to communications systems. Also, image processing and rectification procedures for automating the overlay of these data onto base maps for decision making.
- Miniaturized data acquisition and storage system for advanced platforms (UAVs).
- Direct application for recording of transient electrical bursts, e.g. lightning.
- High capacity, high speed system (Time resolution <1ms; storage > 2 gigabytes).
- Light weight, low volume (<2 kg; <75 cubic cm).
- Advanced platforms (UAVs) having altitude capability between the Earth's surface and 23 kilometers with an endurance of not less than 3 hours, and slow speed (i.e., under 8 meters per second) to permit slow responding meteorological sensors to sample properly.
- Advanced platforms (UAVs) having lift capable of supporting 3-10 kilograms of payload mass and the appropriate volume.
- Advanced platforms (UAVs) having flight altitude, speed, pattern orientation, etc., controllable from the ground using a combination of the GPS and small computer technology (i.e., a GPS/PC-based autopilot).

13.05 Earth-Orbiting Flight Measurement Systems
Lead Center: GSFC

NASA seeks development of smaller, less resource intensive instruments and spacecraft for obtaining measurements from Earth-orbit required by the Earth Science Enterprise program. Proposals are sought for technologies that support advanced capabilities in Earth system science including the following:

- New mechanical and electrical devices and innovative packaging that provide significant reductions in system volume, mass, and power for the whole spectrum of Earth observing instruments such as:
    - Acousto-optic spectrometers and/or digital auto-correlators for passive microwave radiometers.
    - Frequency-agile and variable bandpass optical filters to enable radiometer imaging in frame camera mode.
    - Well-calibrated radiometers for atmospheric correction of multi/hyper-spectral imaging spectrometers.
    - Solid-state, local oscillators and mixers for 1-5 THz heterodyne microwave radiometers.
    - Low disturbance, long-life micro mechanical coolers for 50-80 K focal planes.
    - High energy, solid-state lasers for wind measurements.
- Techniques to improve and simplify ground, airborne, and in-orbit calibration and validation of spectrometers and radiometers as well as to facilitate the transfer of standards from one platform to another.
- Detector systems that cover the wavelength bands of interest to Earth science that require minimal or no active cooling such as SWIR, MWIR, and TIR detector arrays that operate at elevated (non-cryogenic) temperatures

to enable smaller, lighter, and lower power multispectral and hyperspectral solar reflected and thermal infrared imaging systems.

- Miniature passive atmospheric remote sensing systems for tropospheric and stratospheric chemistry measurements, atmospheric dynamics, earth radiation, clouds, aerosols, and other measurements important to monitoring global change. Advanced sensor technologies include, but are not limited to, ultraviolet through far-infrared detectors, ground and flight calibration sources/techniques, and advanced signal processing.
- Approaches that eliminate the need for scanning mechanisms and moving parts.
- Methods to improve operational life of instruments and spacecraft.
- Simplifications to traditional design, development, integration, and test programs for flight hardware.
- Formation flying and management of constellations of Earth observing and remote sensing spacecraft.
- Smart command and data handling systems and increased levels of autonomy for remote sensing spacecraft in low Earth and synchronous orbits.
- Large format, high sensitivity active pixel arrays for smart sensor concepts in the UV thru thermal IR spectral region. High degree of on-focal-plane integration to incorporate signal processing functions and micro-optic beam conditioning. There is a particular desire for arrays which do not require active cooling in order to reduce power and size of future instrumentation.
- Extension of this technology into the far-IR, a region of significant scientific interest not yet benefiting from the same level of sensor development, is of special interest.

13.06 Measurement and Enhancement of Satellite Scientific Data Quality and Applicability
Lead Center: SSC

Proposals are sought for the development of advanced technologies to enhance the commercial application of the commercial remote sensing industry and enhance the commercial application of earth science data. Focus areas are to provide tools for interpretation, visualization or analysis of remotely sensed data; and to provide qualitative and quantitative analysis tools and techniques for performance analysis of remotely sensed data. Areas of specific interest include:

- Visualization of multi-variate geospatial data including remotely sensed data from the following: 1) airborne and satellite platforms, vector data from public and private archives, 2) cartographic databases from public and private sources, 3) continuous surface data held as a raster data model, and 4) 3-D data held in a true 3-D raster model.
- Innovative approaches that contribute to the understanding of data through the display and visualization of some or all of the above data types including providing the linkages and user interface between the cartographic model and attribute databases.
- Innovative approaches for incorporation of GPS data into *in situ* data collection operations with dynamic links to spatial databases, including environmental models.
- Data merge and fusion software for efficient production of commercial digital products.
- Data mining systems to allow content-based searches of ES databases and reduction of bandwidth transmission to essential-only data.
- Techniques to enhance performance of wide-area networks supporting highly distributed data production, archive, and access functions.
- Autonomous classification systems of high-resolution digital data.
- Fusion of science data sets to correlate similar data sets from diverse spacecraft and aerial vehicles and provide unique, commercially useful information products.
- Innovative techniques for the validation of thermal and LIDAR imaging systems.
- Software to commercialize the digital topography and vegetation canopy data products that are obtained by airborne and space-based active optical sensors.
- Innovative techniques to automate quality assurance processes for science data products.
- Unique, innovative data reduction and analysis methodologies and algorithms, particularly for hyperspectral data sets.

13.07 *In Situ* Measurement Systems for Earth Observing Satellites
Lead Center: GSFC

Proposals are sought for the development of *in situ* measurement systems that will enhance the scientific utility of the Earth Science Enterprise program and that will broaden the uses of its systems to include products of interest to commercial and governmental entities around the world including: NOTE: we are not looking for Unpiloted Aerial Vehicles (UAVs), but rather for sensors that could fly on these and other suborbital platforms.

- Autonomous GPS-located ocean platforms to measure and transmit to remote terminals upper ocean and lower atmosphere properties including temperature, salinity, momentum, light, humidity, precipitation, and biology. Similar sensor packages for use onboard ships while under way.
- Autonomous low-cost systems to measure surface and lower atmospheric parameters including soil moisture, precipitation, temperature, wind speed and humidity.
- Systems for *in situ* measurements of cloud radiative properties including extinction, absorption, scattering phase function and phase function asymmetry.
- Small, lightweight instruments suitable for balloon, kite, or small remotely piloted aircraft for *in situ* measurement of cloud parameters and atmospheric trace gases.
- High sensitivity measurement of atmospheric trace gas mixing ratios. Robust instrumentation for unattended operation in harsh environments.
- Systems and devices for measurement of atmospheric aerosol chemical, microphysical, and radiative properties. Autonomy desired for ground-station network applications and deployment aboard aircraft.
- Systems to measure line- and area-averaged rain rate at the surface over lines of at least 100 meters and areas of at least 100x100 meters.
- Lightweight, low-power systems that integrate the functions of inertial navigation systems and GPS receivers for characterizing the flight path of remotely piloted vehicles.
- Low-cost, stable (<1% over several months) portable radiometric sources for field characterization of spectral radiometers.
- Innovative approaches for the gathering, storing, and forwarding of *in situ* measurements using common carrier infrastructures.
- Lightning location techniques to locate VLF sferic sources (5 to 15 kHz) within 100 km at ranges of 2000 km or more.
- Low cost, lightweight, deployable sensors for *in situ* and aircraft measurements of liquid and ice hydrometers in cloud and precipitation systems.
- Hardware and algorithm approaches for wind measurements using spaceborne precipitation and cloud lidars.
- Systems for *in situ* measurements of atmospheric electrical parameters including electric and magnetic fields, conductivity, and optical emissions.
- Wide-band microwave radiometer capable of high-speed characterization of cloud parameters, including liquid and ice phase precipitation, that can operate in harsh environmental conditions (e.g., on-board ships).
- Autonomous GPS-located air borne sensors that remotely sense atmospheric wind profiles in the troposphere and lower stratosphere with high spatial resolution and accuracy.

13.08 Synthetic Aperture Radar for Spacecraft Applications
Lead Center: JPL

The two main problems to solve for spaceborne synthetic aperture radar (SAR) programs are to reduce the radar instrument cost and to increase the use of SAR data among the remote sensing community. Advances in radar technology are sought to enable low cost spaceborne SAR. Technologies which may lead to advances in radar architecture design, hardware, and algorithms are the focus of this subtopic. In order to increase the SAR user community, this subtopic will also consider SAR data applications and post processing techniques. For SAR applications, the frequencies of interest include L-band, C-band, and X-band. The required bandwidth varies from 20 MHz to 300 MHz to achieve the desired resolution. The synthetic aperture technique is also applied to a radar ice sounder, which is a low frequency radar with very high percentage bandwidth. Specific areas in which advances are needed include:

Synthetic Aperture Radar:
- Electronically steerable phased-array antenna architectures.
- Shared aperture, multi-frequency antennas.
- Lightweight antenna structures and deployment mechanisms.
- High-efficiency, low-cost transmit/receive modules.
- Advanced radar system architectures including flexible, broadband signal generation and autonomous radar control concepts.
- Advanced radar component technologies including low-loss RF switch; high-efficiency power converters; high-speed analog-to-digital converters; low-sidelobe chirp waveform generator.
- Data acquisition, storage and on-board processing technology.
- SAR data processing algorithms and data reduction techniques.
- SAR data applications and post-processing techniques.

Radar Sounder:
- Synthetic aperture processing technique to increase resolution.
- Broad-band (100 % or more) low frequency (<100MHz) antenna.
- Highly efficient, broadband, low frequency (<100 MHz) transmitter.
- Low-power, highly integrated radar components.

13.09 Microwave Radiometry Technology
Lead Center: GSFC

Proposals are sought for the development of techniques and/or components that enhance the calibration accuracy of microwave radiometers or save cost and time of development. Both the spaceborne and airborne microwave radiometer systems are included in this category. The airborne radiometers are important scientific instruments in their own right, and they are frequently used to calibrate space-borne instruments. A few examples of well-known space-borne microwave radiometers include the TRMM Microwave Imager (TMI), the Special Sensor Microwave Imager (SSMI), and its next generation, SSMIS, the Advanced Microwave Sounding Unit (AMSU-A, AMSU-B), Microwave Humidity Sounder (MHS) and its newer version, HSB. New ideas of improving the calibration techniques are sought for microwave radiometers such as the examples cited above, both in their on-board calibration sub-systems, as well as pre-launch testing methodology.

On-board calibration systems:
- Improvements in Hot and Cold Reference Targets (also known as Hot load and Cold Load) designs.
- New designs for on-board calibration systems with improved calibration accuracy and long-term stability are desired. Different target designs and/or new calibration sources, e.g., using stable noise generators, can be considered.
- This item also includes improvements in linearity and stability of the instrument so that a stable calibration is maintained over time.
- Optimization of pre-launch calibration methodology for on-board calibration systems. We seek new ideas to improve the pre-launch testing methodologies with an aim to increase the overall calibration accuracy and/or to save test time and cost.

Post launch validation:
- Techniques are desired for validating the instrument's measurement after it is on-orbit, e.g., by comparing with ground truths, or with other similar space-borne instruments in space and time coincidence. The validation can also include techniques that can be used for post-launch geolocation.

Subsystems:
- MMIC receivers and low noise amplifiers for millimeter and microwave radiometers at 60 to 425 GHz. Specific frequencies of interest include 118, 183, 380, and 425 GHz.

- Technologies for 2 to 6 meter deployable or inflatable antennas with a surface finish in the range of 12.5 to 50 micrometers rms that will enable missions with inherently large apertures.
- Compact, low mass, high efficiency microwave sources suitable for radiometers.

13.10 Mechanical and Electromechanical Systems for Spacecraft and Instruments
Lead Center: GSFC

Proposals are sought for new concepts in the areas of structures, mechanisms, control systems, transducer technology, and electronics as they apply to the development of advanced mechanical and electromechanical components or systems for use in spacecraft or precision space flight instruments. The scope of this subtopic includes new materials and fabrication processes as well as new techniques and tools for modeling, analysis, design, and test of mechanical and electromechanical components and systems. The objective is to provide concepts that will enable reliable operation in the space environment with increased performance and efficiency while reducing design and production costs. This topic spans applications that include:

- Regulating and tracking mechanisms like precision mechanisms for scanning the mirror in a Michelson or Fabry-Perot interferometer.
- Antenna pointing mechanisms and inertially stabilized platforms.
- Low power and long life mechanisms that can be used in instruments operating in cryogenic environments of a few degrees Kelvin.
- Magnetic bearings for mechanisms in space flight instruments or spacecraft subsystems such as long life optical beam chopping mechanisms.
- Low vibration reaction and momentum wheels and high speed flywheels for the integration of the spacecraft attitude and power systems.
- Micro-Electro-Mechanical Systems (MEMS) and Micro-Opto-Electro-Mechanical Systems (MOEMS) for instruments.
- Active control of large lightweight structures.
- Vibration isolation platforms that counter microphonic disturbances to delicate mechanisms or the detector assembly in a precision instrument.
- Large spacecraft appendages like solar arrays and instrument booms.
- Large aperture telescopes.
- Electromechanical and opto-mechanical devices for adaptive optical systems such as fast beam steering mirrors.
- Deformable mirrors and focus adjustment mechanisms.
- Stored energy actuators (e.g. spring energy) or phase change alloy type actuators.
- Lightweight precision deployable structures for large aperture telescopes. Structures must be extremely compact for launch and have a reliable and positionally repeatable deployment scheme. Structural stability over wide temperature ranges is emphasized.
- Rapid prototyping methods for medium to large structures (meters3 as opposed to centimenters3). Structures need not be of flight materials.
- Multifunctional structures (e.g. structures that combine electronics and/or thermal management).
- Low cost manufacturing techniques for small and large flight structures which are not mass produced.
- Structures with extremely high or extremely low thermal conductivity.
- Novel deployment-to-orbit mechanisms for multiple (micro, nano, or pico) satellite systems.

13.11 Spaceborne Payload Pointing, Platform Control & GPS Guidance
Lead Center: GSFC

The development of spacecraft flight and ground system technologies for the following items are essential to meet the Earth Science Guidance, Navigation and Control (GN&C) needs of the future: 1) miniaturization of GN&C systems and components, 2) enhanced functionality and autonomy of GN&C systems/components, 3) advanced analytic processes, architectures, and techniques, and 4) GN&C systems utilizing GPS. Specific areas include:

- Enhanced performance as well as reduced cost, mass, power, volume, and reduced complexity of all spacecraft GN&C system elements.
- Components with new or enhanced sensing capabilities.
- Concepts for autonomous guidance of space transportation systems during atmospheric flight phases.
- New concepts for spacecraft control including but not limited to, formation flying techniques such as master/slave satellite strategies, coordinated viewing/pointing, and virtual platforms.
- Control theory, filtering techniques, processing advances, software architectures, and advanced sensors. Improved environmental models for attitude and trajectory determination and prediction.
- Concepts for monitoring spacecraft functions and environmental conditions.
- Assessing health status and optimizing performance through in-flight identification, fault detection stabilization, and re-configurable control.
- Rigid and flexible body control methods that are robust to parametric uncertainty and modeling error.
- Computer aided engineering and design tools and parallel algorithms for analysis and development of GN&C systems. Innovative testbed development capabilities in the area of computer and dynamic simulation of multiple satellites using spacecraft processors to communicate and maintain the formation.
- Methods for in-flight attitude sensor alignment and transfer function calibration.
- Filtering techniques and expert systems applications for near real-time trajectory determination and control.
- Autonomous performance of ground system functions including attitude and trajectory determination, monitoring of spacecraft functions and environmental conditions, assessing ground system and spacecraft health status, ground system fault detection, orbital event and attitude dependent prediction support utilizing advanced techniques such as fuzzy logic and neural networks.
- Low power and mass propulsive attitude control actuators and related subsystem components for nanosatellites in constellation or formation flying missions. Actuators to consume less than one watt of power at three volts, providing impulse bits on the order of one micro-N-sec for 3-axis nanosats or 40 milli-N-sec for spin-stabilized nanosats.
- Low cost momentum wheels that can both store momentum and provide electrical power when used in pairs.

GPS receiver hardware and algorithms that use GPS code and carrier signals to provide spacecraft navigation, attitude, and time:

- Combined navigation and attitude space receivers.
- Advanced antenna designs.
- Navigation techniques that may employ WAAS corrections.
- Relative navigation via a cross-satellite communications link, and formation flight of satellite constellations.
- Navigation, attitude, and control for spacecraft proximity operations.

8.4 SPACE SCIENCE

NASA's Space Science Enterprise seeks to discover the mysteries of the universe, explore the solar system, find planets around other stars, and search for life beyond Earth. From Origins to Destiny, the Enterprise seeks to chart the evolution of the Universe, its galaxies, stars, planets, and life. Its mission includes four science themes: Sun-Earth Connection - SEC (Space Physics), Solar System Exploration - SSE (Planetary Science), Structure & Evolution of the Universe – SEU (Astrophysics), and Astronomical Search for Origins and Planetary Systems. Each of these themes has a committee made up of both NASA and non-NASA scientists. Among their activities is the creation of a scientific roadmap for the next twenty years -- a plan for future space missions that will probe the mysteries of the universe.

http://www.hq.nasa.gov/office/oss/osshome.htm

14 Space-Based Large Telescopes

Innovative products are sought that enable or enhance technologies critical to achievement of large-aperture, high-performance optical space telescopes at greatly reduced cost, weight, and packaging volume. This topic benefits the development of the Next Generation Space Telescope (NGST), a key element of NASA's Origins Program. The NGST is a six to eight-meter aperture telescope that is to be launched in 2006 - 2007. The telescope will be designed to have near-diffraction limited performance in the range of wavelengths between 500 and 5000 nanometers and to operate at 30 K. The mass of the optical system is expected to be less than 1000 kilograms.

14.01 Large Aperture Space Telescope Technologies
Lead Center: MSFC

The NGST, the Hubble Space Telescope Replacement, will be made much more powerful in resolution and light-gathering ability by greatly increasing the aperture size. It also will be necessary to operate the telescope at cryogenic temperatures and at a substantial distance from the Earth. Therefore, low mass of critical components such as the primary mirror and support and/or deployment structure is extremely important. It is also essential to develop actuators, deformable mirrors and other components for operation in a cryogenic environment. In order to meet the stringent optical alignment and tolerances necessary for a high quality telescope and to provide a robust design, there are potential significant benefits possible from employing systems that can adaptively correct for image degrading sources from inside and outside the spacecraft. This subtopic also includes correction systems for large aperture space telescopes that require control across the entire wavefront, typically at low bandwidth. The following technologies are sought:

- New lightweight mirror concepts development.
- New materials that reduce mass and improve performance.
- High precision fabrication methods and equipment to produce the highest quality optical surfaces.
- Metrology during fabrication to monitor, control, and verify results of the process.
- Technologies for testing new mirror materials and shapes in relevant environments.
- Segmented and membrane mirrors technology development.
- New coatings and methods for applying them.
- Lightweight structural concepts that enable packaging the large aperture into the relatively small launch vehicle payload envelope.
- Deployable optical benches to achieve reference baseline dimensions greater than those of the payload envelope.
- Innovative, precision, lightweight deployable mechanisms for segmented and thin membrane primary mirrors operating in a cryogenic environment.
- High resolution (2 nm) long stroke (6mm) cryogenic actuators.
- Powerful new analytical models, simulations, and evaluation techniques and new integrations of suites of existing software tools allowing a broader and more in-depth evaluation of design alternatives and identification of optimum system parameters.
- Active and adaptive mirror systems that compensate for sources of distortion (structural deformations arising from misalignments, thermally driven dimensional changes and dynamics from overall vehicle motions, and moving mechanical systems on-board the spacecraft) to the image produced in the telescope.
- Innovative methods of detecting and characterizing errors.
- New control algorithms and methodologies for turning error information into corrective commands.
- Precision actuation to accomplish corrective measures.
- Embedded microelectronics to reduce the size and mass of an adaptive control system.
- Image stabilization technologies enhancements.
- Measures that reduce the effects of the dynamics from internal mechanisms.
- Innovative solutions for momentum exchange systems.
- Momentum management systems that are not life-limited by consumables.
- Momentum management, pointing and attitude control, and on-orbit metrology systems that are integral with the adaptive and active correction system to achieve high optical performance, robust adaptability, reliability, and long life.
- Develop methods to conduct on-orbit system identification through the acquisition of experimental data for the purpose of correlating computer simulations and diagnosing possible structural dynamic problems. Structural excitation techniques that do not employ consumables should be developed as well.

15 *In Situ* Exploration and Sample Return

Solar system exploration is now embarked on a new phase, one that uses highly capable robotic space systems to explore the atmosphere, surface and subsurface of planets, satellites, and small bodies by means of *in situ* measurements and sample return. Understanding the nature and history of our solar system, the similarities and differences between Earth and other planets, how life may have originated and persisted beyond Earth, and the potential for human habitation within the solar system are specific space science goals for which *in situ* exploration is particularly relevant, if not critical. To accomplish the goals of future missions, innovative science payload technologies are needed for in situ measurements of the atmosphere, surface, and subsurface. Novel devices and approaches are needed for deployment of instrumentation, sample acquisition, transfer to sample collection sites or sample return vehicles, and for positioning of in situ instruments. Innovations are also required to achieve the cleanliness requirements for planetary protection and integrity of samples used for in situ analysis and sample return.

15.01 *In Situ* Science Payload Systems
Lead Center: JPL

NASA's space science missions will increasingly rely on *in situ* characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. Achieving the solar system exploration goals will require innovative components and miniaturized instruments for *in situ* analysis that offer significant improvements over the state-of-the-art in terms of size, mass, cost, power, performance, and robustness. These instruments may be deployed on surface landers and rovers, subsurface penetrators, hydrobots, and cryobots, and atmopheric sondes and probes. These instruments must be capable of withstanding extended operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses. A reasonable target for a science instrument concept is 1 kilogram mass, 1 liter volume, and 1 watt-hour of energy, although for mission critical capabilities, additional resources might be available. Innovations in enabling instrument component and support technologies are also solicited. Topics include new sensors with improved performance relative to the state-of-the-art, as well as miniaturized valves, pumps, injectors, micro fluidics, and integrated sample handling methodologies. A wide range of *in situ* instruments are of interest—geological, mineralogical, chemical, biological, physical, and environmental—with a near-term focus on Mars and Europa. This does not preclude the submission of proposals in areas of longer term interest which include comets, asteroids, Venus, and the outer planets. Examples of technology challenges include, but are not limited to the list provided below.

- Measurement of evolved gases and volatiles from soils, rock, and ices
- Near and far-field compositional analysis of soils, rocks, and ices
- Mineralogy of rocks and soils
- Geological stratigraphy
- Geochronology
- Chemical reactivity of soils, rocks, and ices
- Analysis of particle size distribution and morphology of surface soil and dust
- Measurement of toxic potential of Martian soil and dust with respect to human habitability
- Compositional profiling of planetary atmospheres
- Measurement of dissolved gases, ions, organics, dissolved solids, etc. in liquid water
- Detection & measurement of organic molecules, including chiral analysis
- Measurement of total inorganic carbon and total organic carbon
- Measurement of isotope ratios for carbon, nitrogen, and oxygen in organic compounds
- Measurement of seismic, electromagnetic, and magnetic properties
- Measurement of meteorological phenomenon
- Characterization of the radiation environment (protons, neutrons, energetic cosmic)
- Particles (electrons and protons) and fields measurements for space plasma and solar studies

15.02 Instrument Deployment, Sample Acquisition and Retrieval Systems
Lead Center: JPL

Future scientific exploration of planets and small bodies will require improvements in the tools for *in situ* sample selection, collection, protection, and retrieval, and for placement of instruments on or below the surface. These tools will be required to operate in extreme environments including high temperature, high pressure environments as well as low temperature, near vacuum environments. Novel devices and approaches are needed in the areas of manipulation and positioning of instruments, penetration of surface materials that have a wide range of properties, acquisition and storage of pre-determined amounts of material, protection of samples from handling and environmental damage, placement of samples into analysis systems, and the transfer of samples to collection sites or delivery systems. Example technology concepts include, but are not limited to, the following:

Surface Operations:

- Mini-sample acquisition mechanisms with integrated feedback sensing
- Low-power miniature rock crushing and transport system
- Impact technologies for rock fragmentation
- Impulse cancellation/reduction techniques for sampling devices
- Mini-extendable stinger/plunger end-effectors
- Instrument placement techniques

Sub-Surface Operations:
- Low reaction force coring and drilling devices operating within planetary and small-body gravity environments
- Low power rock ablation for spectrometry of subsurface materials
- Anchoring techniques for microgravity bodies

Atmospheric Operations:
- Instrument deployment mechanisms from balloons and aerobots
- Balloon materials for extreme environments
- Passive entrapment devices for atmosphere/particulate collection

Operations in Wet Environments:
- Sample acquisition in wet environments including mini-pump and transport systems
- Sample acquisition within sub-surface ice environments
- Passive entrapment devices for liquid collection

Innovations for Planetary Protection and Sample Return:
- Sample confinement techniques for sterile insertion and maintenance of uncontaminated samples within a cache container.
- Sample containment techniques (biologic, thermal, and mechanical) for planetary sample return. Techniques should be robust to Mars, space, and Earth re-entry environments.
- Techniques for biological monitoring of samples throughout the sample return mission (Mars, Mars-Earth transit, and Earth re-entry).

16 Astrophysical and Space Physics Observations

The technical requirements to support the Structure and Evolution of the Universe (SEU) and the Sun-Earth Connection (SEC) science themes missions are extremely diverse, which is a consequence of the wide-ranging nature of the investigations. Technology developments are sought in the system context from energy detection through data reduction and scientific visualization needed to implement SEU missions. Technology developements are also needed in the areas of plasma, particle, fields and imaging sensors needed to support SEC missions.

16.01 Technologies in Support of Gamma Ray, Cosmic Ray, and X-Ray Observations
Lead Center: GSFC

The SEU program seeks innovative technologies to enhance the scope, resolution, and efficiency of high energy detection systems. Proposals are solicited for innovations ranging from readout electronics to optics systems that provide order-of-magnitude performance enhancements. Achieving the increased measurement resolutions typical of future SEU missions, requires instruments with substantially larger aperture sizes and focal lengths. Example supporting technologies to enhance x-ray, gamma-ray, and cosmic-ray detection systems are listed below.

- Advances are sought in high-density interconnects for connecting detector arrays. Low power (< 200 mW per linear chain) ASIC electronics for read-out of the strip and pixilated arrays. High density capacitor/resistor arrays on a single substrate to interface strip and pixilated detectors to readout electronics.

- Advances are sought in cascade shower detectors to detect three dimensional development of the electromagnetic cascade shower induced by a high energy gamma ray (>0.1 eV).
- Advances are sought in large arrays (~120x120) of superconducting TES (transition edge sensor) X-ray microcalorimeters (2 eV FWHM at count rates up to a KHz in the 0.3-12 keV band). SQUID based read-out electronics with switching and sampling rates from 1-10 MHz. Robust x-ray filter substrates for cryogenic instruments in the range 50 eV to 12 keV to act as input filters for these arrays. Closely packed 2-dimensional calorimeter array structures employing unique methods of thermal isolation and batch processed fabrication techniques.
- Advances are sought in cryogenic x-ray detection sub-systems technologies including microcalorimeter arrays and tunnel junction arrays integrated with cryocoolers and electronics.
- Advances are sought in large, lightweight optics subsystems technologies including replicated thin shells, conical foil mirrors, spherical optics, and variable line density diffraction gratings, capillary optics, innovative imaging techniques, and multi-layer coatings.
- Advances are sought in lightweight, extendible optical benches, particularly in precision deployment mechanism design, passive thermal control, and disturbance isolation.
- For extendible reflectors, advances are sought in low-mass reflector panels, active alignment control, and nonlinear microdynamics modeling.

16.02 Technologies in Support of Gravity Wave, Radio, Sub-millimeter, Far-IR, and IR Observations
Lead Center: JPL

Technologies of interest in this subtopic tend to be specialized or optimized to meet the specific needs of the SEU theme. Technologies for gravity wave, radio, submillimeter, far-infrared, and infrared wavelengths include the following:

- Ultra-low-noise accelerometers used to enable the detection of fine distortions in space-time due to the arrival of a gravitational wave. These have a sensitivity requirement of <1e-15 g/sqrt(Hz).
- Micro-Newton thrusters required to cancel out the solar radiation force on the spacecraft, correct for fluctuations in that force, and control spacecraft attitude.
- Separated spacecraft interferometers to determine changes in the distance between test masses in different spacecraft separated by ~ 107 km.
- Active and passive cooling technology, for submillimeter emissions, to cool the reflector/antenna/detector areas to temperatures in the 40K - 150K range. Development is needed in lightweight sunshades and advanced high efficiency radiators.
- Cryogenic detectors and electronics, including HT superconducting detectors(bolometers,etc) low-noise amplifiers, digitizers, multi-plexers, low jitter and phase noise oscillators up to 5 THz, and LO amplifiers.
- Phase-controlled, low absorption, reflective coatings for infrared cryogenic Fabry-Perot applications.
- Tunable optical filters for use in cryogenic systems.
- Low-mass, thermally stable precision reflectors and telescope technology(CFR and SiC materials).
- Low-current, superconducting magnets for operation at and below 10 degrees K, and associated flux pumps.

16.03 Heliospheric Plasmas and Fields Sensors
Lead Center: GSFC

Over 99% of the matter in the universe is in the plasma state. The extended corona of the sun, or solar wind, along with the ionospheres and magnetospheres (where present) of the planets, are the most immediate examples. Partial ionization is the rule and in general, fast charged particles coexist with neutral gas exospheres of varying relative density. Research designed to improve our knowledge and understanding of "space weather" requires accurate measurements of the composition, flow, and thermodynamic state of space plasmas. Low energy charged particle analyzers and DC to RF electromagnetic field sensors provide the foundation of this capability based on direct in situ measurement. Complementing direct measurements, fast neutral atom imagers, UV and X-ray photon imagers, and radar imaging all provide wide-ranging remote sensing of energetic phenomena occurring within space plasmas. Plasma and fields instrumentation is often severely constrained by spacecraft resources. Therefore, miniaturization and autonomy are common technological development themes across this entire category of sensors. Specific technologies are sought in the following categories:

Particle Sensors and Imagers
The Sun-Earth connection program seeks novel sensors that enhance the scope, resolution, and resource-efficiency of plasma particle measurements in the energy range from a fraction of an electron volt up to a few hundred keV. Examples of the types of technical innovations that would be of interest include:

- Improved techniques for imaging of the charged particle velocity distribution such that a complete distribution can be measured in a time comparable to or shorter than the ion cyclotron period.
- Direct charged particle velocity measurements using measurement of the particle time-of-flight.
- Spectrographic (mass and energy or velocity) imaging of fast neutral atoms with improved sensitivity and angular resolution.
- Techniques for the high-efficiency conversion of low energy neutral atoms (less than 1 keV) to ions.
- Improved techniques for the regulation of spacecraft floating potential near the local plasma potential, at low local plasma density, or in the presence of very high temperature electron plasmas (keV and higher).
- Miniaturized and autonomous systems for the above.

Field Sensors

- Improved techniques for measurement of the DC electric field (and by extension the plasma drift velocity), especially in the direction parallel to the spin axis of a spinning spacecraft.
- Measurement of the floating potential (relative to local plasma potential) of a spacecraft over the range $-50V < V_{s/c} < 50$ V, in any conditions of sunlight or plasma.
- Measurement of the gradient of the electric field in space around a single spacecraft or cluster of spacecraft.
- Improved techniques (or recovery of old metalurgical techniques) for low noise, high resolution measurement of the DC magnetic field in interplanetary space.
- Improved techniques for the measurement of the gradients (curl) of the magnetic field in space local to a single spacecraft or group of spacecraft.
- Direct measurement of the local electrical current density at levels typical of space plasma structures such as shocks, magnetopauses, and auroral arcs.
- Miniaturized and autonomous systems for the above.

Electromagnetic Imaging Systems

- Improved techniques for spectrometric imaging of UV emissions emanating from regions of energetic plasma phenomena interacting with atmospheric gases, such as the aurora and dayglow.
- Adaptations of UV imaging to diverse spacecraft orbits and vantage points (field-of-view and resolution).
- Adaptations of X-ray imaging to diverse spacecraft orbits and vantage points (field-of-view and resolution).
- Spectrometric imaging of X-ray emissions from regions of energetic particle interactions with atmospheric gases.
- Radar sounding and echo imaging of plasma structures from spacecraft.
- Miniaturized and autonomous systems for the above.

Support Electronics
Miniaturized and autonomous plasma, fields, and photon imaging systems will require the development of novel, miniaturized, low power support electronics to process and analyze the detector signals for delivery to spacecraft systems. Generic functions will make development of custom chips cost-effective in some cases. Examples include:

- Low power digital time-of-flight analyzer chips with sub-nanosecond resolution and multiple channels of parallel processing.
- Low power radiation-tolerant microprocessors and associated autonomous operating systems.

17 Space-Based Optical Interferometers

Optical interferometry figures prominently in NASA's plans for 21st century space science. As part of the Origins Program three major interferometry scientific missions are planned: the Space Interferometry Mission (SIM), the Terrestrial Planet Finder (TPF), and the Keck Interferometer (ground-based). This topic is looking for high-risk, high-payoff, innovative concepts that will help to achieve the interferometry goals, including reduction of cost and schedule. The grand technical challenges of optical interferometry include: 200 picometer positional measurement over distances up to 100 meters; mechanical stabilization to order of 1 nanometer; and system level modeling, integration, and test of interferometer instruments. Relevant technologies include: laser metrology, active optics, thermally stable optics, precision deployable structures, vibration isolation/suppression, realtime control algorithms and software, and integrated modeling software.

17.01 Metrology and Starlight Detection Systems
Lead Center: JPL

The next generation of astrophysics missions will require highly precise control of active optics on flexible structures. Laser metrology gauges provide the sensing for these control loops. These missions have needs in metrology subsystems architectures, components and data processing. Detection of stellar interferometric fringes in beam combiners is critical to measurements of astrophysical objects. A nulling beam combiner at low temperatures is needed for detecting and characterizing extra-solar planets. Innovations are needed in instrument design and fabrication, optical components, and detectors. Performance extension into the 5 to 10 micron regime is desired. Proposals for concepts in the following areas are solicited:

Metrology
- Linear metrology gauges relative accuracy of less than 100 picometers
- Ultra-stable lasers for metrology gauges
- Frequency shifters for metrology gauges.
- Integrated lightweight beam launchers.
- Full-aperture metrology gauges.
- Embedded grating technology
- Optical surface measurements at l/1000 to l/10000 wavelength accuracy.
- Fiber-optic systems and components with low polarization cross-talk for routing metrology laser signals.
- Star simulator for testing a variable (up to 10 meter) baseline interferometer

Interferometeric Detection
- Interferometeric beam combiners at visible and infrared wavelengths.
- Low-background, low noise infrared detectors (5 to 10 micron regime).
- High frame rate/ultra-low read noise CCD and infrared detector arrays.
- Ultra-high contrast (109) beam combining techniques to suppress starlight and image extra-solar planets.
- Low-temperature beam combiners and detectors.
- Wide-band, low reflection coatings.
- Single-mode, infrared fiber waveguides in the 2-10 micrometer regime.
- Wavefront sensors, l/1000 wavelength accuracy.

17.02 Active Optics
Lead Center: JPL

Methodologies, hardware components, and systems to actively control optics either on a spaceborne interferometer or a ground-based interferometer will be required. These systems will concentrate on high bandwidth pathlength control and tip/tilt control required by interferometers. Wavefront control for large aperture interferometers such as the Keck is also of interest. Proposals from the following areas will be considered:

- Multiprocessor computer systems for interferometers.
- Control architecture, design and algorithms for interferometers.
- Thermally stable large field of regard, high accuracy gimbals (+,- 7.5 o, 17 mas 1 s).

- Thermally stable high-bandwidth, momentum-compensated steering mirrors.
- Six DOF pointing and displacement mechanisms, with high pointing stability and low power
- High-precision optical encoders.
- Long-throw, high-precision optical delay lines.
- Automated alignment sensors and systems.
- Thermally stable articulating mirrors for automated optical alignments.
- Thermally stable micromechanical actuators
- Ultra-precise sensors such as nano-g accelerometers and fine guidance sensors
- Infrared wavefront sensors (2 to 10 micron regime)
- Actuators for controlling position and figure of segmented optics.
- Adaptive optics systems and components.
- Deformable mirrors for ground-based telescopes.
- Deformable mirrors with extremely high actuator density.
- Systems to control interferometer Spacecraft constellations, including formation flying acquisition/maintainance sensors, actuators and algorithms
- Multifunctional approaches.

17.03 Ultra-quiet Precision Systems
Lead Center: JPL

Concepts, components, subsystems, algorithms, and software necessary to attenuate vibrational motions of the system and key components when subjected to excitation over a broad frequency range, including low frequencies that may be excited by thermal or other sources will be required. Significant goals are reduction of cost, mass, volume, power, and adverse side-effects such as heat generation; or an increase in performance, robustness and redundancy. Novel methodologies including non-deterministic approaches, algorithms, test data, software in support of high-fidelity, and integrated modeling of complex opto-mechanical systems will be required to meet these objectives. This covers the areas of structural finite element models, acoustic models, thermal models, modeling of vibration isolation and suppression sub-systems, modeling of actively controlled optical systems, and any test data essential to validating the models. The magnitude of the vibrational motions of interest is in the 1-10 nanometer range. A new class of deployable structural concepts and approaches capable of achieving precise post-launch deployment; maintaining structural linearity and repeatability in the deployed condition; and retaining the desired features of reliability, reduced weight and stowed launch volume will be required. The linear baseline of the deployed structures ranges from 10-100 meters. Novel concepts in a deployment system, materials, coatings, actuators, sensors, controllers, power, mechanisms, and others contributing to the final goals are solicited. Areas of interest include:

Vibration Attenuation
- Isolation of noisy subsystems from the structure.
- Attenuating the motion of the structural vibration modes and traveling waves.
- Isolation of the quiet subsystem from the structure.
- Novel sensors and actuators to achieve the desired performance.
- Multifunctional sensors, actuators, electronics, controllers, and power for actuators and other applicable components or subsystems.
- Passive, semi-active or active approaches for vibration attenuation.
- Use of smart materials and adaptive structures concepts.
- Adaptive control-structure capabilities adjustable during the mission operation. Integrated Modeling
- Innovative approach for structural modeling capable of characterizing broadband dynamic response.
- New concepts to reconcile integrated structural models to measured data.
- New techniques to accurately predict synthesized model response from component level tests..
- Structural modeling techniques for thermally induced vibrations in joint-dominated structures.
- Modeling of slosh phenomenon at cryogenic temperatures.
- Integrated design optimization techniques and algorithms for precision optical systems.

- Analytical characterization of nanometer-level static, thermal and dynamic induced structural distortions for optical elements, opto-mechanical components and precision deployment mechanisms.
- Novel test concepts and approaches to verify accuracy of high fidelity integrated model predictions.

Precision Deployables

- Test approaches and concepts that can be validated by ground tests.
- A deployed system that is linear and repeatable within 1 nanometer at structural motions of around 10 nanometers in the space environment including thermal, space effects, etc.
- A deployment system capable of surviving the ground test and launch environments.
- A thermally active or passive system to retain the structural dimensions to within 10 millimeters.
- Precision 10-50 meter long metrology boom deployed to within less than 1 millimeter accuracy at the tip.
- Semi-passive or active approaches to correct for quasi-static deformations to within 1 micrometer.
- Novel use of smart materials and adaptive structures technologies.

8.5 CROSSCUTTING TECHNOLOGIES

In addition, underlying the activities of NASA programs are critical crosscutting technologies that may support multiple Strategic Enterprises. Within this Solicitation, this synergistic crosscutting activity primarily supports the science-based Enterprises of Space Science and Earth Science.

18 Power, Propulsion, and Thermal Technology

A large portion of the size and weight of a spacecraft is required to deliver reliable electrical power, thermal control, and on-orbit propulsion. Future NASA missions depend upon the continued advancement of these critical technologies. NASA seeks innovative concepts and advanced technologies needed for static and dynamic energy conversion, storage, management, and distribution systems for high performance spacecraft and for advanced transportation systems. Advanced thermal control technologies and on-orbit propulsion and chemical propulsion systems for future space missions are areas in which NASA also seeks innovative proposals.

18.01 Thermal Control
Lead Center: GSFC

Future spacecraft, space facilities (manned and unmanned) and instruments will require increasingly sophisticated thermal control technology and may operate in increasingly severe thermal environments. Heat load centers will be more numerous and more widely dispersed, flux levels will increase, and very tight temperature control will be required. Some applications may require significantly increased power levels. Others may require extremely low heat loss for extended periods. Low cost, low weight, and high reliability are prime technology drivers. Specific areas for which innovative proposals are sought include:

Unmanned spacecraft:
- Advanced thermal control of chip level electronics.
- Cryogenic heat pipes and CPLs (8 K to 60 K) with diode and flexible capabilities. Advanced wicks (2 micron or less) are also of interest.
- Low mass, high performance modular heat pumps for both manned and unmanned (spacecraft and balloon) applications.
- Advanced thermal control coatings such as variable absorptive and emissive property coatings/devices and white, sprayable, conductive thermal control coatings with low outgassing characteristics are of interest.
- Methods for enhancing thermal control through electrohydrodynamics, advanced materials with high conductivity and low CTE, advanced radiators, improved contact conductance (predictable, repeatable, high thermal conductivity), and long-life high temperature insulation (above 2300 K).
- Instrumentation and automated software that will enhance system thermal control and monitoring; for locating component failures and for performing isolation and recovery operations.

Life and biomedical space experiments:
experiment supplies and specimens. Current storage systems operate at +4 C and -20 C. Their power consumption, mass, and crew maintenance time are areas needing improvement. Future missions will be longer duration (i.e.,

temperatures and R/F equipment types. Areas in which innovations are solicited include the following:

- Energy efficient, reliable, low-maintenance refrigeration and freezing system concepts for thermal storage at low-temperatures (+4 C, -20 C, & -70 C) and cryogenic (-183 C) storage for laboratory supplies and
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  for the amount of rack space.
- Concepts for logistically efficient transfer/transport of frozen specimens on and between spacecraft, and for processing on Earth while maintaining specimen storage temperatures.

Human space missions:
thermal environments than in the past. There is a need for advanced thermal hardware to provide highly efficient, lightweight, reliable internal and external active thermal control systems (ATCS) for piloted spacecraft and

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  75 K or does not change density upon freezing; room temperature phase change devices; and a controllable, reliable water evaporator for use in a vacuum. Lightweight, two-phase systems with self-diagnostic, repair and
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  design codes that integrate thermal, mechanical and power systems to minimize total mass.
- Lightweight, high-efficiency heat pumps (275 to 370 K).
- Flexible, lightweight, micrometeoroid tolerant, highly reliable radiators that can be stowed for transport and deployed for use on spacecraft or planetary surfaces.

18.02 Energy Conversion and Storage and Electric Power
Lead Center: LeRC

Innovative concepts for systems and components are solicited in the areas of both static and dynamic energy conversion systems. Power levels of interest range from tens of milliwatts to many kilowatts. This area includes

systems. Additionally, NASA programs require energy storage systems having high energy-density and cycle life. This includes rechargeable batteries, fuel cells and competing alternatives with high-power-density such as

- Photovoltaic technology with targeted cell efficiencies over 30 % and array performance up to 1000 watts per kilogram and 400 watts per square meter. Potential concepts include rigid arrays, thin film arrays, and various

  in low temperature, low intensity or high temperature, high intensity conditions
- Advanced solar thermal power conversion technologies for earth orbiting spacecraft and/or orbit transfer vehicles. Concentrators may be rigid or inflatable, primary or secondary and address issues such as

  pipe or direct absorption technologies intended to minimize mass and volume. Topics of interest in power conversion include the investigation of compact heat exchangers, advanced materials, and control methods, as

  materials, heat pipes, pumped loop systems, and packaging and deployment. Also of interest are highly integrated systems which combine elements of the above subsystems and show system level benefits. Thermal-to-electric conversion concepts are sought that would utilize Radioisotope Heater Units (RHUs) or milliwatts to 100's of watts and efficiencies greater than 20 %. Systems of interest include AMTEC, thermophotovoltaics, thermoelectrics and Stirling. Small light weight heat reaction systems are also needed. Concurrent with NASA's trend toward micro-satellites, NASA also has an interest in power systems based on micromachining fabrication techniques.

- Nickel-hydrogen and nickel metal hydride battery technology with goals of at least 100 watt-hour per kilogram and 10-year life in LEO and GEO for spacecraft and space systems. Also, lithium and lithium-polymer batteries for planetary spacecraft and probes with goal of 200 watt-hour per kilogram for low and/or wide temperature operations.
- Proton exchange membrane and solid oxide fuel cell and fuel cell-electrolyzer systems.
- Portable, rechargeable energy storage concepts with increased energy density over Ni-Cd and Ni-H2, but which require only hundreds, not thousands of cycles. Proposed concepts for EVA and in-cabin energy storage can include a variety of approaches such as secondary batteries, fuel cells, ultra or super capacitors or flywheels; however, the primary criteria are high energy density (both weight and volume)portability, and safety.For unique applications requiring few "cycles" very high energy density primary battery systems are of interest where sufficient energy storage can trade against rechargeability.
- Demonstration as a pilot project of a flywheel energy storage unit for use as an uninterruptable power source (UPS). The flywheel system will be run in parallel with an existing UPS for 60 Hz backup power.
- Future planetary missions require high specific energy and high energy density primary and rechargeable batteries capable of operating at low temperatures. Planetary probes require primary batteries capable of providing 500 Wh/kg specific energy and 1000 Wh/l at ambient temperature. Further, these batteries must be capable of delivering 30-50% of their ambient specific energy at temperatures as low as -100 C. Lithium primary with advanced cathode materials and electrolytes and other advanced electrochemical systems having these capabilities are of interest. In the rechargeable lithium battery area, the primary technology drivers are specific energy (150 Wh/kg), energy density (300 Wh/l), cycle life (1000 deep discharge cycles) and low temperature operating capability (-60 C to ambient). Rechargeable lithium ion batteries with advanced anode and cathode materials and liquid/polymer electrolytes and other advanced battery systems capable of meeting the above performance criteria are of interest.

18.03 Power Management and Distribution
Lead Center: LeRC

Innovative concepts utilizing advanced technology are needed to manage and distribute power in lighter, smaller, cheaper, more durable, and high performance spacecraft and to improve reliability and reduce overall costs (including operations) for advanced transportation systems. New concepts in power control and distribution, power applications which greatly impact specific systems, and technological advances that substantially improve a broad range of space power and aircraft systems are of interest. Advances for power management and distribution (PMAD) systems are sought in the following areas:

- Materials, surfaces, and components that are durable for atomic oxygen, soft x-ray, electron, proton, and ultraviolet radiation and thermal cycling environments, lightweight electromagnetic interference shielding, and high-performance, environmentally durable radiators.
- Low Earth orbital atomic oxygen simulation and protective coating technologies.
- Advanced electronic materials, devices and circuits, including, but not limited to, transformers, transistors, integrated circuits, capacitors, electro-optical devices, micro electro-mechanical systems(MEMS), sensors, low-profile low loss magnetic cores, and packaging with improved characteristics capable of high-temperature, low-temperature (cryogenic), or wide-temperature operation or radiation resistance for use in PMAD systems, motor drives, electrical actuation, or electro-mechanical systems. Electronic devices and circuits to deliver high-efficiency power at less than 3 volts (logic levels).
- Management, control and monitoring of power systems, adjustable speed drives, or autonomous operation of space power systems.
- Advanced packaging technologies which enable integral thermal control of space power electronics while reducing package volume and mass or which combine electromagnetic interference shielding and thermal control.

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  health management concepts.
- Advanced PMAD electronics for small low-cost spacecraft to simplify interfaces, streamline integration and testing, as well as to reduce size and mass through the use of new technologies and topologies.
  Advanced power conditioning devices for space and Earth science payloads to reduce size and mass through

  wide range of regulated voltages.
- Modular, integrated spacecraft PMAD building blocks which drastically reduce system size, mass, and recurring cost through the use of the highest levels of integration based on monolithic, application-specific

  advanced power packaging techniques, and flexible reusable architectures.

18.04 In-Space Propulsion

satellites, reusable vehicles, and interplanetary spacecraft). Innovations are sought to enhance propulsion and fluid system capabilities for functions including orbit insertion, orbit maintenance, precision positioning, de-orbit,

technologies at the component, sub-system, and system level will be considered. Key aims of this subtopic are technology advancements which will lead to 1) significant miniaturization, 2) reduced system, operations, and/or

functions.

Areas of interest include:

- Electric and chemical propulsion technologies for satellites and spacecraft less than 50 kilograms, including the micro electro-mechanical system (MEMS) class. These propulsion concepts should emphasize system
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  low-leak rate valves, regulators, flow control devices, multifunctional components, and ignition sources.
- Electric propulsion technologies for Earth-space and planetary transportation applications, including thrusters, advanced power processing, and propellant system technologies.
  High performance monopropellants for small spacecraft applications. Included in this area are ignition

  functions.
- Radiation-cooled rocket chamber materials for long-life (6 hours) operation in high-temperature, aggressively oxidizing combustion environments. In particular, innovative fabrication technologies for ceramic matrix
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  propulsion system mass and volume by a factor of two or better, while maintaining or improving reliability and performance of existing chemical components and systems. Components include propellant storage and

  devices, and thermal control hardware for chemical systems. For electric systems, technologies of interest include energy storage and delivery, propellants and feed, initiation and long life, and control.

future aerospace systems. Advancements are sought that reduce mass, volume, processing/fabrication cost, and design analysis cost and inaccuracies for a broad range of end applications to spacecraft, launch and space transfer

utility, enable in-situ non-destructive monitoring and test, and provide active adjustment and adaptation are also sought . Technologies are needed which extend the reliability and life of systems operating in environments which may include combinations of extreme and cycling temperatures, extreme mechanical stresses, chemical interactions, and space environments including vacuum and ultra-violet, electromagnetic fields, solar particles and galactic radiation, atomic oxygen, micrometeoroids, and planetary surface atmospheres and dust.

19.01 Materials, Material Processing, and Coatings for Launch Vehicle and Spacecraft Components

Lead Center: MSFC

NASA seeks innovative materials and structures technologies for improving performance and affordability of future aerospace systems. Advancements are sought that reduce mass, volume, processing/fabrication cost, and design analysis cost and inaccuracies for a broad range of end applications to spacecraft, launch and space transfer vehicles, aircraft, and their power and/or propulsion systems. Improvements that increase component functional utility, enable *in situ* non-destructive monitoring and test, and provide active adjustment and adaptation are also sought. Technologies are needed which extend the reliability and life of systems operating in environments which may include combinations of extreme and cycling temperatures, extreme mechanical stresses, chemical interactions, and space environments including vacuum and ultra-violet, electromagnetic fields, solar particles and galactic radiation, atomic oxygen, micrometeoroids, and planetary surface atmospheres and dust.

Enhancements in the following areas are of interest:

- Innovative fabrication technology that combines advanced materials and processing techniques; non-autoclave curing and alternate curing techniques, e.g., x-ray or electron beam, UV.
- Rapid, multidimensional preformed fabrication for continuous fiber-reinforced composites with simple or complex geometry and/or large dimensions.
- Manufacturing processes for LOX-compatible and reusable composite lines, ducts, and cryotanks.
- Production of lightweight tooling and mandrels for composite structures.
- Processing techniques for non-uniform composite structures.
- Damage-resistant composite structures (residual strength property measurement and prediction after impact).
- Advanced materials and processes for both oxygen-rich and high-temperature applications.
- Advanced ceramics/composites for propulsion system components including turbopump components, lines/ducts, cooled and uncooled nozzle applications, and valve components.
- Improved structural integrity materials for use in end-item component processing with rapid-prototyping technologies.
- Process control instrumentation for characterization and verification of material properties, including thermal, optical, electrical, mechanical and moisture absorption and composition utilizing new and innovative state-of-the-art technologies.
- Coatings technologies vital in developing advanced high-temperature superalloy-, intermetallic-, and ceramic-matrix composites with enhanced structural, environmental, and use-temperature capability.
- On-orbit repair for coating, bonding, seals, and structures.
- Adhesive bonding materials with high-performance capabilities in extreme environments such as cryogenic temperatures and elevated temperatures above 520 K.
- Surface preparation techniques for substrates such as aluminum, steels, titanium, epoxy and graphite composites, glasses, and ceramics.
- Paints and other surface coatings for space flight applications that are adherent to standard substrates and are free of flaking, low outgassing, stable alpha and epsilon, stable electrical behavior, and resistant to ionizing radiation and atomic oxygen.
- Thread locking compounds that have a range of predictable shear strengths and low outgassing.
- Optical cements with a stable refractive index resistant to ionizing radiation and low outgassing.
- Atomic oxygen resistant flexible coatings for materials such as thermal blankets and flexible composite structures. Proposals are also sought for innovative thermal spray or cold spray coating processes, and for novel uses of existing thermal spray processes that substantially improve material properties, combine dissimilar materials in new and useful ways, or drastically increase efficiency, equipment life, or allow new applications previously limited by the current state of the art. Applications of interest include but are not limited to:

- Dense deposits of refractory metals, ceramics, and metal carbides. Thickness greater than 0.125 inch is of particular interest.
- Application of thermally sprayed coatings to non-metallic and composite materials to enhance or extend utility or service limitations.
- Coatings for protection of materials to be used in gaseous oxygen-rich environments.
- Coating or spraying processes that allow forming of dense, high quality metallic or ceramic structural parts of complex geometry.
- Improvements in thermal spray hardware that improve operational life of frequently replaced components, particularly for plasma spray hardware.
- Thermal spray processes, hardware, or materials that allow application of high melting point materials to heat-sensitive substrate materials.
- Thermal spray or liquid metal forming without the use of a vacuum chamber.

19.02 Thermal Protection Materials and Systems for Hypersonic Vehicles and Spacecraft
Lead Center: ARC

Future hypersonic vehicles and spacecraft require new thermal protections materials (both ablative and reusable) and novel thermal protection systems that are lightweight and durable with lower fabrication and operational costs than those currently available. Design, analysis, and optimization of such materials systems requires innovative applications of computational and experimental technology to account for complex high-temperature multiphase phenomena that occur in the external flow, on the heatshield surface, and inside the materials. This subtopic solicits innovative concepts for novel lightweight and durable, rigid or flexible, reusable or ablative materials and systems having good thermal-shock resistance and temperature capabilities in the range from 800 to 3100 K. Possible reusable materials include refractory oxides, carbides, nitrides, borides and certain refractory metals. Mass efficient ablative materials using novel technologies are also sought. Possible material forms are fiber-fiber composites, fiber matrix composites, foams and felts, and various woven systems, as well as thin film, multilayer technologies. New minimum-weight, load-bearing or non-structural thermal protection systems using new components and processing methods are of interest, as are concepts for new and innovative lightweight solutions to cryogenic tank insulation for application to new reusable launch vehicles. Important proposal considerations are reduced weight, reduced fabrication or operational costs, improved performance, and improved robustness in adverse environmental conditions.

This subtopic also solicits new computational and experimental technologies for accurate measurement and modeling of mass and energy transport through TPS materials with detailed treatment of conductive, convective, and radiative heat transfer effects; for investigation of gas/solid interaction phenomena in reacting flow environments; and for rapid trajectory-based computational techniques. Technology applications of interest include the extension of computational end experimental methodologies to the phenomena listed above; diagnostics for high enthalpy test facilities; and experiments to validate computational methods and to measure relevant TPS material physical properties.

19.03 Materials for Propulsion and Power
Lead Center: LeRC

Technologies to be addressed relate to advanced materials, their development, and their application to primary propulsion systems (aircraft gas turbines, rocket-based combined cycles, and rocket engines) and auxiliary power sources in aircraft and space vehicles. Proposals are sought to address the following areas:

High temperature polymers and polymer matrix composites for 18,000 hour life applications at temperatures from 280 to 320C:

- Materials and related technologies (automated cure, resin transfer molding, weaving and braiding) to enable low-cost manufacturing of composite components.
- Cost competitive non-mutagenic diamines for use in polyimides, especially low cost routes for synthesis of alpha-alpha prime-bis(4-aminophenyl)-p-xylene(BAX).

- Electron beam curable polyimides for high temperature applications.
- Processable adhesives of low void content.
- Overlay coatings for oxidation protection.

Monolithic nickel-base superalloys and intermetallics, especially TiAl and NiAl:
- Low-cost processing and joining technology.
- Alloying to improve toughness of NiAl.
- Fiber coatings to improve compatibility with commercial oxide or carbide fibers.
- High thermal conductivity copper alloys and composites.

Ceramic matrix composites:
- Stronger, more creep-resistant high-temperature fibers.
- Environmentally resistant and/or low-cost fiber coatings (SiC reinforced and oxide/oxide composites).
- More affordable and stronger, tougher, and more environmentally-durable composites.
- Low cost alternatives to fiber reinforcement.

Lubricants, Tribology:
- Liquid, vapor phase, and mist lubricant formulations for gas turbine engine applications to 400 C.
- Wear resistant and fretting fatigue resistant coatings for titanium alloys.

Thermal Barrier Coatings(TBC) with emphasis on nondestructive evaluation techniques with the potential to provide:
- Quality control of plasma sprayed and physical vapor deposited TBCs.
- Operational inspection of TBC coated parts enabling identification/overhaul/replacement prior to engine damage.

19.04 Structures for Propulsion and Power
Lead Center: LeRC

Proposals are sought for innovative and commercially viable concepts for propulsion and power structural and mechanical systems. Innovative structural and mechanical concepts for advanced space propulsion systems are also sought. The focus is on problems related to structures that operate at extreme temperatures, in hostile aero-thermo-chemical environments, and at high stresses. The objective is to provide structural and mechanical concepts that enable reliable operation, increased efficiencies, reduced design-to-production time, and reduced life-cycle costs.

Machinery Dynamics: Innovative mechanical systems for controlling destructive aeroelastic and rotordynamic instabilities and vibration in turbomachinery. Specific items of interest are:
- Blade vibration dampers
- Blade Deflection and Tip Clearance Measurement Systems
- High Temperature (e.g. 1000oF) Coils, Probes, and Touchdown Bearings for Magnetically Suspended Turbomachinery
- High Speed (e.g. 50 to 100K rpm) Touchdown Bearings for Magnetically Suspended Flywheels

Structural Mechanics Computational Methods: Analytical tools for simulating the performance of critical structural components and systems; optimizing and tailoring their capabilities; and modeling life-cycle performance from material selection to system requirements. Areas of interest are:
- Life-Cycle Modeling
- Composite structures
- Multi-disciplinary design optimization and tailoring
- Material processing modeling

Bearings: Proposals are sought for innovative and commercially viable concepts for advanced analysis modeling of rolling element bearings and/or fluid film bearings for use in high-speed, high-load, high temperature, aircraft turbine engines or mechanical drive systems. The advanced concepts should provide next-generation design tools to increase design confidence, reduce design and analysis time for bearings, reduce development cost, and significantly reduce the development time for aircraft propulsion systems. The advanced codes should consider (but not be limited to) ball, cylindrical, tapered, and spherical rolling elements as well as fluid film journal and thrust bearings. The codes should also consider (but not be limited to) stress analysis, life analysis, lubrication effects, temperature effects, rotordynamics effects, misalignment, and distortion. State-of-the-art processing algorithms as well as effective graphical user interfaces should be considered.

Life-Prediction: Life-prediction models and failure theories for assessing the durability and integrity of structural components manufactured from advanced high-temperature materials. These materials include: advanced metallics; intermetallic, polymeric, ceramics and ceramic matrix composites. Technical areas of interest include:
- Damage mechanics and viscoplastic constitutive models
- Fatigue crack initiation and growth models
- Brittle structures modeling
- Fracture mechanics/modeling

Experimental Mechanics: Experimental research at the coupon level investigating the physical mechanisms of deformation and damage evaluation in advanced aeropropulsion materials. Experimental research at the subelement level aimed at the verification/validation of analytical models and analysis methods under prototypical leading conditions. Areas of interest are:
- Non-destructive evaluation methods and standards
- Mechanical test methods and standards
- Benchmark structural testing

Probabalistic Durability, Reliability, & Risk Assessment: Economically viable, safe, and environmentally-compatible new structural systems incorporating state-of-the-art materials must contend with a host of failure modes while operating under severe thermal-mechanical loading conditions. Assessing the risks of achieving adequate structural durability and reliability will rely heavily on our ability to probabilistically model deterministically observed material flow and failure behavior. Such behavior can be determined from both laboratory experiments on coupons and simulated or actual components where data exist or can be economically generated. Probabalistic analysis research is to concentrate on macroscopic crack initiation type failure mechanisms and specimen/component fracture modes. Fracture Mechanics or Damage Mechanics based approaches are not being sought under this element. Major failure mechanisms include: Fatigue, Excessive Inelastic Deformation, Creep-Rupture, Creep-Fatigue Interaction, Cyclic Relaxation, Creep-Fatigue-Environmental/Coatings Interactions, Thermal and Thermomechanical Fatigue, Cumulative Damage, Multiaxial Interactions, Brittle Fracture, Wear, Galling, Fretting, and Buckling.

19.05 Space Environmental Effects and Contamination
Lead Center: MSFC

Innovative concepts are sought for the development of materials, processes, electronics and systems to mitigate, and/or survive the space environment, and techniques that predict the environment experienced by spacecraft in the near-Earth and deep space environments. This subtopic is concerned with the electromagnetic fields, ionizing radiation, meteoroid and orbital debris, contamination, plasma and thermosphere, and thermal and solar components of the environment. Specific areas for which proposals are sought include:

- Miniature sensors to measure the vehicle environment and life-predicting tools based on previous flight-experiment data and models.
- Elimination of contamination on spacecraft surfaces and/or mechanisms for in-flight cleaning.

- Approaches for measuring, predicting, and verifying spacecraft molecular and particulate contamination, including reliable molecular monitoring systems, compact particulate-monitoring systems, and mass-transport models to predict molecular direct-transfer, backscattering, particle transport, and surface effects.
- Low cost, lightweight materials and protective coatings that mitigate environmental effects.
- New processing and application techniques that reduce the cost of current, space-qualified materials and coatings.
- Cost-effective methods for ground-based simulation of the environment.
- Techniques for electrically grounding spacecraft to mitigate spacecraft charging and mitigation design guidelines.
- Preventing or mitigating the effects of space plasma electrical discharges on solar arrays and surfaces.
- Instrumentation to determine absolute electrical potentials of interplanetary and planetary surface spacecraft.
- Stable, electrically conductive but thermally advantageous coatings for spacecraft surfaces.
- Electrically insulating materials with the capability of "bleeding off" buried charge.
- Instrumentation to detect *in situ* buried charge in insulators.
- Controlling spacecraft potentials actively or passively.
- Other methods to mitigate harmful effects of space plasma and spacecraft charging.
- Damage location and mitigation technologies for meteoroids /orbital debris.
- Development of mitigation design guidelines for ionizing radiation.
- Electromagnetic Interference (EMI) susceptibility characterization of new technology devices.
- Developing innovative, low-cost electronic components or systems that show tolerance to the infrared (IR) environment.
- New materials and coatings, including electrically conductive, thermal-control coatings that mitigate the environmental effects.
- New techniques to reduce the cost of current, space-qualified materials and coatings.
- Device for cleanrooms to measure particulate and/or molecular contamination of surfaces exposed to gaseous environment. Adaptation of quartz crystal microbalance technology, or other innovative technology, for use in monitoring cleanrooms and sample processing enclosures. Sensitivity of ng/cm2 deposition desired, and the device should be portable and designed to not add contamination to the cleanroom.

19.06 Smart Materials and Embedded Components for High Performance Aerospace Systems
Lead Center: LaRC

Innovative concepts are being sought for the development of smart materials and components for applications in high-performance aerospace systems. Material systems of interest include piezoelectric and electrostrictive materials, optical fibers, films, and coatings for sensing external stimuli. Novel techniques are being sought for embedding sensors, actuators, and electronics into composite systems for active shape control and vibration stabilization. Novel approaches are sought for actuation devices that have high displacement resolution at cryogenic temperatures and hold position without power. Innovations in microsensors and microactuators are also needed.

Innovations also are being sought in the use of actuators and sensors for deployment and adjustment of structures for controllability, system identification, vibration attenuation, shape control, static adjustment, enhanced reliability, and reduced costs. Computer tools also are needed for modeling and analyzing the dynamic performance of smart material systems including piezoelectric coupling, dynamic response, and finite element modeling approaches. Such tools should be able to be run on desktop computers, account for test conditions, and have design and analysis capability.

Passive damping, active damping, and low shock release devices also are sought for single, on-orbit deployment (e.g., solar arrays and antennas) where simultaneous deployment is critical. Damping devices must be insensitive to a wide temperature range, operate continuously in either direction, be adjustable and provide manual disengagement for quick reset. Release devices, besides being low shock, must be low power and mass, temperature insensitive and must be quick to replace/reset. In addition, these damping and release devices should require a minimal space to operate, and must withstand launch and landing loads.

Monolithic rheological fluid devices for holding mechanisms are solicited. Conventional rheological fluid clamps and brakes offers compact holding mechanisms with typically very modest requirements for holding power. However, these devices frequently require substantial capacitors for operation. Recent advanced in thin film supercapacitors and ultracapacitors offer opportunities for integration of compact, monolithic integration of electrical and mechanical function.

19.07 Low Density/Reduced Mass Materials for Aerospace Systems
Lead Center: LaRC

Innovative approaches are being sought for the development of low-density materials, processing and fabrication technology, forming and joining technology, and process modeling to lower the weight, improve structural efficiency, and reduce the acquisition costs of airframe structures, launch vehicles, and spacecraft. Low-density materials include polymers, polymer-matrix composites, light metallic alloys, metal-matrix composites, metal laminates, inorganic glasses, ceramics, ceramic-matrix composites, carbon-carbon composites, refractory-matrix composites, material system blends, composite reinforcement architectures, adhesives, films, sealants, coatings and insulating systems. The anticipated airframe structural applications of low-density materials include a variety of service environments and temperatures ranging from cryogenic to elevated temperatures projected for supersonic and hypersonic airframe structures. These low density materials also may have applications on small satellites, manned platforms and associated instrument subsystems in space environments ranging from low Earth orbit to geosynchronous orbit.

Future spacecraft designs require substantial weight reduction in order to reduce cost yet maintain equivalent or improved performance. New materials technology that provide high thermal conductivity with reduced mass is sought. In many applications, these materials must be capable of carrying structural loads as well. Low coefficient of thermal expansion (CTE) is also beneficial in many applications. Low cost manufacturing methods of these materials are sought, as many current technology materials are prohibitively expensive to produce. Applications in both cryogenic and room temperature regimes are solicited. Specific areas for which proposals are sought include the following:

- Spacecraft structural material.
- Aeroshells.
- Low CTE optical benches and mirrors.
- Instrument and electronics box enclosures.
- Mechanical interface material between electronics boxes and spacecraft baseplates.
- Cost reduction methods for producing candidate materials.

19.08 Non-Destructive Evaluation of Materials and Structures
Lead Center: LaRC

Innovative concepts are being solicited for the development of non-destructive evaluation (NDE) sensors and instrumentation, and computational modeling for signal processing and data interpretation. Evaluation sciences include ultrasonics, laser ultrasonics, optics, video optics/metrology, thermography, electromagnetics, acoustic emission, and x-ray radiography, and related management of digital NDE data. NDE technologies may be applied to characterizing material properties, assessing effects of defects in materials; evaluating of mass-loss in materials; *in situ* monitoring and control of materials processing; detecting cracks, porosity, foreign material (inclusions), corrosion, and dis-bonds in structures; detecting cracks under bolts; and *in situ* monitoring of structural durability. NDE concepts would be applied to low-density material systems of interest to NASA including polymers, polymer-matrix composites, light metallic alloys, metal matrix composites, metal laminates, inorganic glasses, ceramics, carbon-carbon composites, refractory-matrix composites, material system blends, aluminum-lithium weldments, composite reinforcement architectures, adhesives, sealants, advanced bearings, and coatings. The anticipated structural applications to be considered for NDE development include a variety of service environments and temperatures projected for subsonic, supersonic and hypersonic aircraft structures, and launch vehicles and spacecraft. There is additional specific interest in noncontacting, remote, rapid, and less geometry sensitive technologies that reduce acquisition costs or improve system sensitivity, stability, and operational costs.

Proposals for innovative and commercially viable concepts for NDE of propulsion and power structural systems are sought. Focus is on nondestructive materials characterization and life prediction of high temperature engine materials and components operating at high stresses and in hostile aero-thermo-chemical environments. Materials include superalloys and monolithic ceramics, and polymeric, intermetallic, and ceramic matrix composites.

19.09 Bonding and Joining Technologies
Lead Center: MSFC

NASA seeks innovative technologies for bonding and joining of materials to improve the performance and affordability of future aerospace systems. Advancements are sought that improve joint efficiency, allow joining of a wider range of materials, improve the quality and cost-effectiveness of the joint, and extend the understanding of factors influencing these characteristics.

- Technologies and processes are sought for joining of aluminum alloys, especially in the application of cryotankage and structures for future space vehicles. Of particular interest are those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites. Additionally, methods for low-cost fabrication in the more common aluminum alloys and other structural metallic alloys are of interest.
- Technologies are needed to improve control of welding, brazing and other joining processes as they are applied to joints for aerospace vehicles. These technologies should be compatible with the quality requirements for aerospace vehicles, and should include process control technologies as well as non-destructive examination methods.
- Techniques are needed for in-space welding and its associated operations, including welding, brazing, cutting, joint preparation, and non-destructive examination. These techniques would be applied to aluminum, stainless, and titanium alloys in plate and tube forms.
- Techniques and processes are sought for the joining of dissimilar refractory metals and ceramics capable of withstanding repeated cycling to or long-term sustained operation at very high temperatures (approaching the melting points of the materials being joined). Materials of interest include, but are not limited to, refractory metals such as TZM and titanium, ceramics such as mullite, alumina or silicon nitride, various carbon-carbon composites, graphite and CVD diamond. The requirement for sustained operation at high temperature severely restricts the use of active metal braze techniques, while the requirement for repeated high temperature cycling makes it essential that detailed consideration be given in the proposal to problems of CTE mismatch. Material properties of particular interest in the bonded assemblages include the electrical conductivity of the joint and its stability in both oxidizing and reducing atmospheres at high temperature. Prospective uses for the techniques developed under this subtask include the construction of ultracompact, highly-efficient furnaces and evaporators to enable particle experiments on the Space Shuttle and Space Station, bonding leading-edge components in supersonic aircraft such as the National Aerospace Plane and fabrication of structural components for use on space missions close to the Sun such as Solar Probe. These techniques should have broad application in the commercial arena where the use of advanced ceramics and composites has been severely hindered by the inability to join such materials into components capable of withstanding the same harsh environments as the materials themselves.

19.10 Inflatable Structures and Systems
Lead Center: JPL

A new class of deployable space structures has emerged that has tremendous potential for enabling missions based on using large, low cost, light weight and mechanically reliable structures. The technology has advanced to the point of accommodating the design and manufacture of thin membrane structures with enough geometric precision to be considered for a number of applications including booms, solar-array support structures, sun shade support structures, planar array antennas, solar concentrators, and reflector antennas. Proposals that take advantage of the inherent capabilities of inflatables to provide low package volume for transport while enabling large volume applications will be considered. Elements of this technology include space rigidizable and thin membrane film materials; manufacturing, handling, processing and assembly techniques for flexible materials; concepts for the control of deployment dynamics of inflatable structures; ground based deployment approaches for large inflatable structures and analytical performance simulation for these unique structures. Requirements are for new techniques for the space based rigidization of thin flexible materials that are long term dimensionally stable.

The availability of thin polymer films that have high radiation resistance and lend themselves to handling, processing and fabrication of high precision doubly curved surfaces are desirable. New and innovative deployment control concepts that account for the effects of residual air and the release of materials strain energy while maintaining member expansion rates and prescribed dimensional changes are needed. New ground based deployment test techniques for large inflatable structures that utilize fixturing to offset the effects of gravity loading, vacuum drop testing and 0-g aircraft tests or some combination of them needs to be addressed. The value of this technology for specific applications will be realized when analytical tools are available for the prediction of structural, dynamic, thermal and long term dimensional stability of these structures.

19.11 Balloon Vehicles & Aerobots
Lead Center: GSFC

Innovations in materials structures and systems concepts have enabled lighter than air vehicles to play an expanding role in NASA’s space and earth science programs. Smaller robotic balloons, known as Planetary Aerobots will carry scientific payloads into the atmosphere of Mars, Venus, Titan and the outer planets in order to investigate their atmospheres *in situ* and their surfaces from close proximity. Their envelopes will be subject to extreme environments and must support missions with a range of durations. Miniature balloons capable of long duration flight also are emerging as an important tool in terrestrial climate investigations and weather prediction. Such balloons also have potential commercial significance for communications. A new generation of stratospheric balloons based on advanced balloon envelope technologies will be able to deliver large balloon craft and payloads of several 1000 Kg to above 99.9% of the Earth’s absorbing atmosphere and maintain them there for months of continuous observation. The Ultra Long Duration Balloon (ULDB) with volumes up to 1 million cubic meters must survive a demanding set of environmental conditions beginning with the fabrication of the material and balloon through launch, ascent and float. NASA is seeking innovative and cost effective solutions in support of this development activity in the following areas (proposers should specify the size range of vehicles to which their technologies apply):

- High strength to weight composite envelope materials suitable for fabrication into balloon vehicles.
- Efficient and cost effective balloon envelope seaming fabrication and inspection techniques.
- Buoyancy control methods involving no consumables to limit balloon diurnal altitude excursions or temperature/differential pressure fluctuations and/or enable altitude control needed for planetary missions.
- Autonomous precision parafoil and parachute systems for recovery of terrestrial klallooncraft and targeting of planetary probes and sondes.
- Deployment and inflation of balloon envelopes in planetary atmospheres.
- Latitude trajectory control for altering balloon trajectories to avoid overflight of no-fly zones on earth and enable global reconnaissance of the planets.
- Innovative balloon design concepts for including zero-pressure, superpressure, Montgolfere and reversible fluid balloons.
- Techniques for contamination and sterilization of planetary balloon materials to meet planetary protection requirements.

20 Design Tools, Systems Analysis, and Simulation

This topic provides advanced visualization and computational capabilities to rapidly design and simulate aerospace products in a collaborative environment linking science, technology, and engineering teams. Tools and interfaces (computer-to-computer and human-to-computer) are required at several levels of fidelity to provide the means to "virtually" assemble, visualize and test vehicles and mission scenarios. Traditional methods (based on physical principles) and non-traditional methods (based on intelligent learning systems) will aim at addressing uncertainties, risk, and cost. Methods for rapid verification and validation of new design and simulation models are included, and should address new areas such as microspacecraft technology. Risk of including such emerging technology will be reduced by integrating advanced process and product models with actual hardware and software components.

20.01 Advanced Concepts of Virtual Spacecraft Design and Visualization
Lead Center: JPL

There is a critical and growing need to achieve better mission designs and hardware, with fewer resources, in less time. From a mission and system perspective, enhanced performance and reduced cost requires: uniform system information storage, seamless integration of tools and applications, continuity of products through the mission life-cycle, and efficient methods for optimization. Design environment innovations must include collaborative development processes, and rigorous validation of decisions and products, with scalable, open architectures. Other required elements are: interface tools that allow efficient creation and modification of mission scenarios with minimal support by software engineers; and methods for collaborative scenario visualization, including advanced displays, language, and adaptive interfaces.

- Advanced human/computer interface: 2D and 3D displays; effectors (manipulation of virtual objects)
- Interactive and collaborative agents: natural language interface; user guidance; connection to underlying agent-based infrastructure. Interfaces and tools for web-based collaborative computing and design.
- Scenario specification and selection: graphical and linguistic programming.
- Discipline tools: object-oriented design environment architectures, object reuse, and object instantiation for maximum flexibility; object request brokers; mega-programming and tools control languages.
- Full life cycle: database containing documentation, hyperlinks, and standard product formats.
- Validation: compliance matrices, peer review support, design walk-through support, comparison of results obtained by new methods with those from traditional methods.
- Verification: tools for virtual system and hardware prototyping and performance verification.
- Advanced product models: smart product models and object modeling languages, analytical, behavioral, simulation and CAD model integration with objects.
- Non-deterministic tools: intelligent non-deterministic tools to provide uncertainty predictions for design and analysis assumptions. Application of uncertainty technologies, to establish an initial reliability based design, in order to remove conservatism in traditional margin-of-safety design approaches.
- Automatic tool interoperability: publish and subscribe architectures.
- In order to reduce design cycle time, innovative approaches to systems requirements capture are needed, perhaps using software models. The new approach should be based on some fundamentally new scheme for producing system requirements and flowing them down to subsystems; it should provide a capability to "execute" requirements against a (changing) mission scenario, testing whether the requirements can satisfy the scenario and if not, where the mismatches occur. It must also allow designs to be continuously tested against requirements for compliance as the designs evolve.

20.02 Advanced Design, Analysis and Simulation Tools
Lead Center: GSFC

Instrument Modeling and Simulation
The continued need to reduce cost of future microwave to x-ray scientific instruments requires innovations in design, modeling, analysis and verification. An integrated, reusable, multidisciplinary, collaborative approach using modeling and simulation tools, and multidisciplinary processes are essential. Areas of interest are:

- Efficient, integrated end-to-end modeling and analysis tools for characterizing the performance, parametrically optimizing the design, verifying the design, and "virtual testing and calibration." This is to include tools for active optical systems particularly for the diffraction-limited image retrieval, and the wavefront retrieval of segmented or deployed optical systems.

- End-to-end instrument systems simulation tools that include the integration of the measurement phenomena, the environment and the instrument subsystems, especially the optics, electro-optics, opto-mechanics, sensors and signal processing.
- Smart Product Models and Object Modeling Languages, analytical, behavioral physical properties integrate with design and modeling tools.
- Non-deterministic tools to provide uncertainties and to use reliability rather than margin-of-safety for design validation.

Mission, Spacecraft, and Ground Segment Systems Design and Modeling
There is a growing need to achieve better mission designs, with fewer resources, in less time. From a mission and system perspective, there is need to have a single system data repository, seamless tool interoperability, continuity of products through the mission life-cycle, and efficient methods for mission optimization. These design environment innovations must include collaborative development processes, and rigorous validation of decisions and products. Areas of interest include:
- Discipline Tools: object oriented architectures, object reuse, and object instantiation.
- Advanced Product Models: Smart Product Models and Object Modeling Languages, analytical, behavioral, simulation and CAD model integration with objects.
- Automatic Tool Interoperability: publish and subscribe architectures, Object Request Brokers, mega-programming and tools control languages.
- Full Life-cycle: database contained documentation, hyperlinks, standard product formats.
- Validation: model validation, compliance matrices, peer review support, design walk-through support.
- Product Standards: STEP-ISO 10303, JAVA, DORBA, OML, etc.

21 Avionics, Data Systems, and Data Storage

This topic seeks innovative technologies that significantly reduce the mass, volume and cost of spacecraft and multispacecraft missions through technical advances in microelectronics and advanced flight computing technologies, guidance, navigation and control systems, and through modular and multifunctional spacecraft architectures that integrate spacecraft subsystems. These goals are to be achieved together with increasing the functional capability of the systems, and improving their system reliability. System on a chip solutions, advanced computing technologies, component packaging, integrating spacecraft subsystems, new methods for attitude sensing, three-dimensional-chip stacking and multichip modules, and advanced design automation are among the many concepts being considered in a revolutionary redesign of spacecraft.

21.01 Microelectronics for Space Systems
Lead Center: JPL

Innovations are sought that significantly reduce the power, mass, volume and cost of spacecraft through advances in microelectronics, computing technologies, and avionics architectures. These goals are to be achieved together with increased functional capabilities and improvement of system reliability. The technologies being sought include:

- Systems on a chip technologies that integrate telecommunications, power management, data processing and storage, or data sensors technologies into a common microsystem.
- Three-dimensional VLSI, chip stacking, multi-chip-module stacking and other advanced packaging techniques.
- Low power components and advanced power management techniques.
- High performance, low power and low cost subsystem interface.
- Low temperature microelectronics components.
- Low power, COTS-based radiation tolerant (including SEU) components.
- Space qualifiable, high-density, non-volatile mass memory.

- Fault tolerance design techniques for severely power and mass constrained environments and extreme long life missions.
- On-board maintenance design and analysis.
- Advanced design automation.
- Low power, high bandwidth integrated fiber optic transceivers with spacecraft network interfaces.
- Design automation, emulation tools, and environments for end to end hardware, mission application software, and operating system developments appropriate for space and high use of COTS derived hardware and software components.
- Concepts and designs for real time *in situ* test and validation of design integrity and performance for spacecraft systems.
- High resolution, high sampling rate analog-digital converters, and digital signal processing hardware components with algorithm design environments for rapid design and prototyping.

21.02 Highly-Integrated Multifunctional and Adaptive Structures for Aerospace Systems
Lead Center: LaRC

NASA seeks concepts for reducing spacecraft size and mass, and for improving the performance of aerospace vehicles through the use of highly-integrated multifunctional and adaptive structures. Multifunctional structures combine two or more functions in load-bearing structural elements. For example, a multifunctional structure may incorporate imbedded electronics, thermal management, and radiation shielding in a lightweight composite panel. An adaptive or smart structure may incorporate sensing, processing, and actuation so that it can respond to changes in its environment, reconfigure its geometry, control its dynamics, or repair itself when damaged.

Innovative technologies are sought in the following areas:
- Techniques for the structural integration of low-volume electronics packaging such as chip-on-structure, chip-on-flex (flexible circuitry), and imbedded electronics.
- Concepts for integrating electronics, thermal management, radiation shielding with lightweight composite structures.
- Concepts for integrating lightweight composite optics and support structures for compact instruments.
- Methods to rapidly assemble and disassemble or repair highly-integrated multifunctional structures or imbedded electronics.
- Reconfigurable structures that incorporate imbedded actuators or smart materials to enable changes in geometry
- Adaptive structures that are capable of reactive responses to environmental stimuli.
- Self-healing materials.
- Electrochromic materials for active control of surface thermal and optical properties.
- Multifunctional structural elements that incorporate lightweight radiation shielding materials to protect astronauts from the harmful effects of galactic cosmic rays and solar particle events.
- Lightweight radiation shielding materials that enable the use of lower-cost commercial off-the-self microelectronic parts in high radiation environments.
- Multifunctional structures that incorporate both power generation and telecommunications functions.
- Lightweight, load-bearing polymer and plastic batteries.
- Interchangeable structural components that can be used for more than one function.
- Integration of two or more spacecraft systems functions in miniature components for micro-spacecraft and sensorcraft.

21.03 Autonomous Guidance, Navigation, and Control for Aerospace Systems
Lead Center: JPL

Innovative concepts for autonomous guidance, navigation, and control for aeronautic and for space systems including new methods and high-precision low-power, and low-mass sensors and actuators are solicited for future NASA missions. Specific areas for which proposals are sought include:

- Micro-star and -feature trackers, micro-inertial measurement units and micro-reaction wheels with masses on the order of hundreds of grams.
- Environmental models to enhance attitude sensor measurements and spacecraft dynamics simulations.
- Advanced architectures, algorithms and software for high precision autonomous control of formation flying spacecraft. High precision G&C constellation sensors including optical, celestial, and RF.
- Miniature spacecraft control capable of autonomously monitoring spacecraft functions and environmental conditions; assessing health status and optimizing performance through in-flight identification, fault detection, stabilization, and re-configurable control; utilizing fuzzy logic, neural networks, and control techniques.
- Advanced techniques for control of both rigid and flexible body control, that are robust parametric uncertainty and modeling error, to improve system reliability, operational capability, and to reduce life cycle cost. Digital filter algorithms to achieve precision pointing and tracking performance with micro-measurement and actuation systems.
- Advanced architectures, algorithms, and software for high precision autonomous controlled landing and sample return on small planetary bodies. This includes sensor system, algorithms hazard avoidance and rendezvous and docking.
- Computer-aided engineering and design tools as well as parallel algorithms to better manage complex tasks required for guidance and control. Advances in these tools should allow faster trade studies, cut analysis costs, allow quick prototyping of flight software, and provide reliable interpretation of real-time simulations.
- Concepts, architectures, and algorithms for guidance of space transportation systems during atmospheric flight phases. Emphasis is on technology that enhances system availability under various atmospheric conditions and maximizes vehicle autonomy.
- Guidance and navigation methods for proximity operations in Earth orbit based on use of the Global Positioning System (GPS).
- Autonomous onboard guidance and relative navigation techniques (hardware, software, sensors) for the formation flying of satellites. Position accuracy on the order of a few centimeters is a goal. Navigation techniques can utilize, but are not limited to the GPS/WAAS.
- GPS receiver hardware and algorithms that use GPS code and carrier signals in innovative ways to provide spacecraft navigation, attitude, and timing information.
- Techniques for the optimization of control functions to enhance the performance of aeronautical vehicles in the face of real parameter uncertainties.
- High resolution optical or other nonintrusive techniques to measure position, and rates of a magnetically levitated body (e.g., bearings). This would be at moderately high sampling rates, (i.e., more than 100 samples /sec).

21.04 Data Management and Electronics for Aerospace Subsystems
Lead Center: GSFC

Proposals in data systems technologies are sought that will allow enhanced science requirements, reduced levels of mission funding, shorter schedules and reduced availability of flight electronic components. The following technology innovations are sought:

- Subsystem data transfer - communications between various spacecraft subsystems and instruments. Development of technologies and architectures that increase the rate of data transfer above 20 Mbits/s are necessary to achieve the autonomous control and science data requirements.
- Intra-system data transfer - communications within the spacecraft subsystem (between cards within a box). Technologies for communications within a box that would replace the conventional passive backplanes to achieve data throughput.
- Volatile data storage - large capacity Solid State Recorders (SSRs) are required to store data until the next ground. Components and packaging techniques that would allow greater density and lower cost SSRs for higher science data rates and smaller spacecraft.
- Non-volatile data storage - components and systems to record data and retain it without power. Removed from the flight configuration and played back on the ground.

- Ruggedized recorders - components to support recording requirements 0of balloon projects.. Technologies that allow 1 Terabit non-volatile recorders to be dropped from balloons (up to 130,00 feet altitude) to the earth (10-g shocks).
- General purpose data processing - higher levels (spacecraft computers that match or exceed the commercially available desktop computers) of general purpose CISC and RISC processing.
- Special purpose data processing - higher levels of onboard science data processing such as histogramming, feature recognition and image registration are necessary to match the data gathering capabilities of future instruments with the limits of spacecraft to earth communications. Development of technologies such as Digital Signal Processors (DSP) and related hardware is necessary to address this future need.
- Configurable hardware - pure hardware solutions with on orbit design flexibility. Technologies such as radiation hardened Field Programmable Gate Arrays (FPGAs) and reprogrammable architectures.
- Low-power electronics - low voltage (<5 V) technologies. Low voltage, such as 3.3 V or 2.5 V or lower technologies to achieve the power constraints of smaller spacecraft.
- Multiprocessing architectures - components, architectures and protocols to achieve parallel scalar computers on board spacecraft.

NASA projects continue to face the goals of decreased payload weight and volume and increased functionality. This effort is to develop miniaturized microelectronic systems utilizing advanced substrate technologies and high-density component packaging techniques, such as chip-on-board and stacked configurations. NASA is soliciting the following technologies needs to incorporate into miniaturized instrument and spacecraft subsystem electronics modules for next-generation spacecraft:

- Higher density and greater functionality in a miniaturized scheme.
- "Order of magnitude improvement" (weight and volume) over traditional packaged parts with printed wiring board configurations.
- Non-traditional substrate materials (silicon, diamond-like materials, etc.) to address challenges in thermal and interconnect.
- State-of-the-art miniaturized contacts as interconnect between layers in stacked packaging.
- Capability for technology insertion as instrument and spacecraft electronics subsystem modules.

22 Instruments and Sensing

NASA has a strong and ongoing interest in advanced instrument and sensing technologies to enable new and improved measurement capabilities across discipline and Enterprise lines. NASA is seeking innovative technologies for remote and in-situ instruments that provide improved sensitivity, spatial resolution or imaging performance; better frequency or energy coverage, better overall efficiency and robustness; and lower cost. Of primary interest are technologies that have the effect of reducing instrument demands on mission resources (such as mass, volume, power, cooling requirements, or cost).

22.01 Spectroscopic and Multi-spectral Imaging Sensors in the UV to Far IR
Lead Center: JPL

Advances in state-of-the art imaging, multispectral imaging systems, and spectroscopic systems in the wavelength region from 10 nm to 1 mm are sought. This includes detectors, readout electronics, and technology for the conversion of electromagnetic radiation to an electrical signal, and the conditioning and transmission of the signal from the focal plane array. Innovations that result in significant reduction of instrument mass, volume, power or data rate with simultaneously improved scientific return, are of particular interest. Of special interest are technologies that benefit NASA's emerging Origins thrust, including large format, high sensitivity arrays with stable performance and radiation tolerance covering the 0.5-20 micrometer range; hybrid IR arrays (including novel intrinsic, extrinsic, and bandgap-engineered materials; InGaAs detectors; quantum well infrared photodetectors, and higher-temperature or uncooled infrared focal-plane arrays); and long wavelength IR detection systems with ultra-low noise, with the goal of single photon counting. The following technology innovations are sought:

- Readouts for deep-cryogenic detectors with low noise, low leakage and reduced focal plane power dissipation. Cryogenic technologies of interest include cryo-CMOS, GaAs, germanium, and superconductors.
- Sensor readout electronics with emphasis on low-power, single-chip imaging systems, optical readouts and couplers, readouts for high background, long wavelength detectors, high-speed, large format arrays for optical communication in visible and IR. Advanced readout systems with on-chip signal processing such as on-focal-plane digitization with high resolution (14 bits dynamic range), dynamic range management, and specialty imagers such as star trackers, fringe counters, and sensors for wave-front correction.
- Robust and highly sensitive UV detectors in large format arrays. Single photon counting is a goal, and solar blindness is a significant advantage.
- Detector/array calibration and characterization techniques, particularly for challenging applications in extremely low signal/background environments.
- Solid state polarimeter detectors including both linear and full stokes vector devices.
- Linear photon counting arrays emphasizing wavelengths at 355, 532, and 1064 nanometers (e.g., Geiger Mode APD).

22.02 High Energy Sensing

Lead Center: GSFC

Advanced detectors, detector arrays, readout electronics and other supporting and enabling technologies are needed to support next-generation Earth, space, planetary, and life science missions. Proposals are solicited for innovations ranging from new detector concepts to improvements to existing detectors that provide order-of-magnitude performance enhancements. The following capabilities in x-ray, gamma-ray, and cosmic-ray detectors and supporting technologies are desired:

- Double sided fine pitch (100 micron to 0.5 mm) silicon strip x-ray and gamma-ray detectors. Must be capable of being arrayed to increase area.
- High energy resolution Ge strip and pixel detectors. The spatial resolution of the pixels or strips should be as small as 0.5 millimeters.
- Technologies for increasing the collecting area to telescope mass ratio in x-ray region of 500 eV to 30 keV (e.g. inflatable and deployable structures).
- Low power (< 200 mW per linear chain) ASIC electronics for charged particle, x-ray, and gamma-ray detectors.
- Flight-qualified, high-density interconnects for connecting arrays of segmented semiconductor detectors.
- Development of improved growth and characterization techniques for Cadmium Zinc Telluride (CdZnTe) material for use in gamma-ray detectors.
- Large arrays (~120x120) of superconducting TES (transition edge sensor) x-ray microcalorimeters (2 eV FWHM at count rates up to a KHz in the 0.3-12 keV band).
- SQUID based read-out electronics for large arrays of TES microcalorimeters. Switching and sampling rates from 1-10 MHz.
- Closely packed 2-dimensional calorimeter arrays employing unique methods of thermal isolation and batch processed fabrication techniques.
- Robust x-ray filter substrates for cryogenic instruments in the range 50 eV to 12 keV.
- Small (<2 mm x 2 mm) low noise wire bondable resistors (100-200 Mohm) with less than 4% resistance changes from room temperature to 1 K.
- High-sensitivity, high-energy-resolution, solid-state scintillation detectors.
- Silicon detector arrays (e.g., CCDs or active pixel sensors) with x-ray response in the 1 keV to 50 keV range for spectrometer applications.
- GAS micro-strip detectors or micro-gap detectors, optimized for low energy x-ray operation in relatively low-rate environments.

- High density capacitor/resistor arrays on a single substrate, to interface strip detectors to analog ASICs.
- Pixelated Cadmium Zinc Telluride (CdZnTe) arrays with pixel sizes in the range of 3 mm as well as 500 microns.
- Pixel arrays of high-resolution germanium detectors with sizes near 1 mm.
- High-performance analog VLSI electronics for readout and processing of signals from both CdZnTe and Ge arrays.
- Focusing optics for hard x-rays (grazing incidence mirrors) for energies to at least 100 keV.

22.03 Microwave, Millimeter and Submillimeter Sensing Technology
Lead Center: JPL

Many NASA future astrophysics, space science, planetary and atmospheric remote sensing programs and missions require microwave-to submillimeter wavelength capability. There are current needs for spectrally pure radiation sources for heterodyne applications through 10 THz, novel light weight diffraction limited antenna systems, low loss THz optics, large bandwidth transmitters and receivers in the 3 cm to 30 micron wavelength range. Pressing requirements are for 1) heterodyne sources in the 1.2 to 3 THz region, 2) very low power backend spectrometers and 3) broad banded sources with 50+mW output in the 60-120 GHz range. More long term requirements are for radiometer system components which can be integrated into very small, low cost, low power receiver systems and millimeter wave very large bandwidth/data rate transmitter and receiver systems. There is also beginning to be some interest in high resolution submillimeter wavelength imaging technology. The focus is on low cost durable technology for application on rocket, balloon and aircraft platforms and at remote/autonomous observatory sites. The technology should also have the potential for adaptation to space applications with lifetimes of 5 years or more. The possibility of cooled operation should be evaluated since many Earth remote sensing receivers typically operate near LN2 temperatures and astrophysics receivers are cryogenically-cooled to liquid Helium or lower temperatures to achieve near quantum-noise-limited performance.

For the heterodyne remote sensing systems, there is an emphasis on 1) broad band (10%) tunable sources with at least a few micro watts output in the 1.2 THz to 10 THz frequency range and 2) 120-1200 GHz sources capable of delivering 20% bandwidth and 100+ micro watts of power with less than 6 watts DC input. Additional source needs include 1) broad band (20%) high power 20+mW active multipliers (x2 and x3) above 60 GHz and 2) broad banded (20%) solid state sources capable of generating 50+mW in the 40-300 GHz frequency range. Preference will be given to fundamental oscillator sources. All of the sources should be phase lockable and should be able to achieve less than 25 kHz line width below 1200 GHz and less than 100 kHz line width above 1.2 THz. In addition to the source needs, the long term goal of this effort is to be able to build complete MMIC heterodyne receivers so special attention will be paid to higher-frequency and higher-output power MIC and MMIC technology.

The specific needs are as follows:

- Broad band (10-20+%) low power solid state local oscillator sources capable of delivering 100+ micro Watts CW in the 120-1200 GHz region and 1+ micro Watt CW in the 1.2-10 THz region. Broad band mixers suitable for use in very sensitive heterodyne receivers have been developed in this frequency range and are currently limited to by the availability and performance of the local oscillators. A single local oscillator source that could tune over any significant portion of the 1.2-3 THz band with a few micro watts of power would find immediate use in several different programs. Preference will be given to fundamental frequency sources that require less than 30 W of power and could be used in long lifetime applications.
- Robust, compact, solid-state, phase-lockable oscillator or active multiplier sources with 50+ mW and 20+% band width in the 60-120 GHz Range.
- Very compact low power high efficiency sources that could be integrated into MMIC receiver systems in the 120-300 GHz frequency range.
- Heterodyne receiver integration at the circuit and/or chip level is needed to extend monolithic microwave integrated circuit (MMIC) capability into the submillimeter regime. Integration of all or part of the local oscillator, multiplier chain, mixer, and intermediate frequency amplifier is one example. There is also a specific need to demonstrate radiometer systems using phased-arrays and MMIC LNA(Low Noise Amplifier)

radiometers from 60 GHz to 300GHz or higher. There is also a need to demonstrate arrays of high performance radiometers for imaging through 1.2 THz.
- Low power multi-channel spectrometers that analyze intermediate frequency signal bandwidths as large as 20 GHz with a frequency resolution of <1 MHz, that are small and lightweight, and that use low power (<5 mW per channel) with high stability and lifetimes greater than five years.
- Compact and reliable millimeter and submillimeter instrumentation that produces low noise images simultaneously in multiple spectral bands.
- Lightweight and compact radiometer calibration references covering 100-1000 GHz frequency range.
- Lightweight, field portable, and compact radiometer calibration target references covering frequencies up to 1000 GHz. The reference must be temperature stable to within 1 Kelvin with a minimum of 3 temperature settings between 250 and 350 Kelvin.
- Low cost special purpose ground based receivers to detect signals radiated from satellites that are already in space for estimating rain rate, water vapor, and cloud liquid water.
- Very large bandwidth/data rate millimeter wave transmitters and receives for the next generation of earth to space based communications.

22.04 Cryogenic Support Systems
Lead Center: GSFC

Future space missions will have operational lifetimes of 5 to 15 years and will require similar lifetimes for cryogenic cooling systems. Both the lifetime and the reliability of the cryogenic systems are critical performance concerns. Mechanical coolers, radiative coolers, stored cryogenic fluids and combinations of these will be considered. Of interest are long life, low vibration, low mass, low cost, high efficiency cryogenic coolers for cooling detectors, telescopes and instruments; for the storage and liquefaction of cryogenic propellants; and for hybrid systems in the 0.05 to 150 K temperature range. The following are of particular interest:

- Highly reliable, efficient, low cost Stirling, pulse tube, reverse Brayton, magnetic, solid-state cooler technology and hybrid systems, including hybrids with radiative coolers. Emphasis will be placed on technologies leading to small, low mass, low cost cooling systems.
- Low cost compressors and pulse tube cooler efficiency improvements for 0.1 - 10 W cooling in the 7 - 120 K range for space missions; coolers for robotic and manned missions to the Moon and Mars (requirements from 100 W @ 20 K with 1 year life to 10 W @ 90 K with 7 year life and oxygen liquefiers for use on Mars over the 3 W to 400 W range); a 0.5 W @ 100 K cooler that can start after 4 years of storage at temperatures down to 100 K; phase change thermal reservoirs or passive storage technology in the 100 - 250 K range for returning samples from planets, asteroids, and comets; and novel micro-scale coolers for integrated focal plane packages.
- Innovative technologies for: hybrid coolers using sorption refrigeration lower stage integrated with a radiative upper stage to provide 100 mW at 10 to 40 K; temperature stability enhancement for solid hydrogen sublimation stages in continuous 10-K sorption cryocoolers: low cost, light weight cryogenic (60 K to 120 K) radiators: active and passive vibration cancellation of mechanical cooler generated vibration, both at cryogenic and ambient temperatures. Other areas of interest include: stable, high conductivity interface materials, high conductivity, low coefficient of thermal expansion (CTE) materials; and high conductivity, flexible thermal links.
- Future missions to the Martian or Lunar surface will take advantage of indigenous resources for producing propellants. Liquid oxygen, and potentially other cryogens, will be produced and stored on the planet surface. Innovative technologies are needed for the cryogenic support systems for these propellant production and storage units. Specific technology areas include high capacity liquefaction systems for oxygen, cryocooler systems with high cooling capacity (25 watts), and very low heat leak oxygen dewars.

22.05 MEMS and Meso Scale Processes and Devices for Instrument Systems
Lead Center: JPL

NASA urgently requires miniature instrument systems and their components which will significantly impact the overall size, mass and power requirements of both robotic and human missions. This subtopic specifically solicits proposals for devices and instruments that utilize micro electro-mechanical systems (MEMS) or meso scale fabrication techniques or process developments which have specific application to the fabrication of such devices (e.g. three dimensional high aspect ratio fabrication, self assembly, large area replication, etc.). This subtopic addresses the application of MEMS or meso scale fabrication technologies for *in situ* micro-instruments which are capable of operating in space and planetary environments under stresses that might include severe heat, cold, vacuum, high impact, and radiation. Innovations in miniaturization are desired not only in sensors (motion, chemical, biological, geological, environmental, electromagnetic, spectral, spatial, etc.), but also in enabling technology such as: vacuum pumps; micro power systems, thermal and power management; packaging; sample collection and processing; and mechanisms for deployment and mobility of sensors and antennae. The recent increase in emphasis on biological and chemical *in situ* analysis and the requirement for drastic reductions in size, weight and power consumption of spacecraft and instruments, creates an opportunity to propose ultra-miniaturized instruments which might utilize combinatorial methods (arrays of thin film sensors) spectroscopic tools (Raman spectroscopy, gas chromatography, capillary electrophoresis, mass spectroscopy) or miniature suboptical microscopy (scanning electron or atomic force microscopes).

Preparation for the human exploration of Mars has been established as a NASA priority. Accordingly, we also solicit MEMS or meso scale micro-instruments designed to measure and monitor habitability, to control *in situ* resource utilization facilities, or to facilitate communication and mobility on the Martian surface. The next generation of spacecraft will use deployable structures for many purposes such as antennas, solar sails, and telescopes. Micro-instrument concepts will be entertained for sensing structure motion and for structure control. Research instrumentation is needed for fundamental studies of basic phenomena, design code validation, and experimental tests in aerospace facilities such as combustion labs and drop towers. Of special interest are techniques that quantify multiple parameters at multiple spatial points to provide 2D and 3D data in turbo-machinery, around airframes, and in microgravity fluids. Time history data is also important. Fluid parameters of interest include temperature, pressure, density, and velocity, chemical composition. Surface parameters of interest include temperature, pressure, strain, deformation, and defect detection. Proposals are also solicited for educational products that bring inexpensive micro instruments to the classroom, either at the K-12 or at the university level. Proposals should be comprehensive, addressing instructional materials, in-service training, and distribution mechanisms in addition to hardware. Of particular value are products that simulate actual or proposed *in situ* instrument payloads. The latter might be distributed with corresponding simulants of planetary material, and could be coordinated with mission activities.

22.06 Instruments for Exobiology
Lead Center: ARC

Exobiology seeks to understand the origin and evolution of life and life-related processes and materials throughout the universe. This requires a specialized cadre of advanced analytical instruments and systems for future solar system exploration missions. In light of a pending sample return, Mars is of special interest for both Earth-based laboratory applications as well as flight experiments. New analytical devices must be highly accurate and precise while performing meaningful analyses on very small samples containing exobiologically-important elements (C,H,N,O,P, and S) and their compounds, e.g., H2O, NOx, CH4. Typically, advanced instruments would identify and measure biogenically-important chemical and elemental components of extraterrestrial atmospheres, soils, ices, sedimentary rocks, and minerals, e.g.,evaporites, clays, and silica, cometary materials. Miniaturization and other techniques to decrease hardware complexity and increase flight capability of the devices or systems for efficient use of spacecraft resources is paramount. Examples include, but are not limited to, the following:

- Gas chromatographs, including innovative detectors, columns, and samplers, for identification and detection of gases and organic compounds at parts-per-billion levels.

- Infrared reflectance and transmittance spectrometers and subsystems to conduct molecular spectrometry of extraterrestrial surface samples and to identify and measure the C, O, and N isotopes contained in CO_2 and NO_x with precision of 0.1 % or better.
- Electrochemical or other elemental and geochemical devices or sensors to sensitively measure composition of single or multiple extraterrestrial surface and atmospheric components, e.g., H_2O, CO_3.
- Novel or advanced chemical analyzers, e.g., ion mobility spectrometers, Raman spectrometers, for molecular analysis of nanogram or smaller quantities of exobiologically-important molecules.
- Remotely-operated device which illuminates and provides full color images of rocks and soils with magnification range of 2-100x.
- System for obtaining and delivering representative extraterrestrial materials e.g., Mars soils, from a minimum depth 1 meter for return to Earth.

Containment systems for returning the extraterrestrial materials samples (atmosphere, evolved gases, rocks, particulates or dust, and core sections are all desired) to Earth after collection. Such systems must isolate and maintain pristine (uncontaminated) samples with retained volatile during handling and transit to Earth. Forward and backward biological isolation of the sample is critical.

23 Spacecraft Miniaturization Technologies

A renewed thrust to reduce cost and enhance science missions can be achieved with revolutionary advances in miniaturization over traditional spacecraft systems. Micro (10 Kg) and nano-satellites (<10 Kg) of all varities will enable new missions that are currently impractical.

23.01 Near Earth Nano-Satellite Technology
Lead Center: GSFC

It is scientifically desirable to fly one hundred nano-satellites in a constellation to make multi-point measurements of key physical processes between the Sun and Earth. The successful development of these nano-satellites will enable a class of lightweight, low power, low cost, high technology science missions, capable of making both in-situ and remote onboard measurements. Each nano-satellite will be fully functional and weigh a maximum of 10 kg, which includes all onboard propellant mass. As a reference, the nano-satellite should be considered a cylindrical spacecraft with dimensions on the order of 30 cm diameter by 10 cm high. The recurring cost goal for manufacturing and testing these nano-satellites is less than $500K each, such that one hundred nano-satellites can be produced within a cost cap of $50M. It is expected that all onboard electronics survive a radiation total dose rate of 100K rads over a 2 year mission lifetime. Proposed concepts in the following technology areas will be considered:

- Advanced, miniaturized propulsion thrusters and/or feed system components for both orbital maneuvers and attitude control, with associated control electronics operating at 3.3 V and power consumption ~ 1 W.
- Solutions for high levels of electronics integration, in order to effectively combine spacecraft subsystem electronics and instrument electronics into the smallest possible mass, power, and volume.
- Onboard RF communications electronics capable of transmitting data to the ground and receiving ground commands from a distance of 3-5 Earth radii. A reasonable target total mass is 0.5 kg and power consumption is 500 mW, with a data transmission rate of 10 Kbps and a command rate of 1 Kbps. It is expected that the tracking system be coupled with this communications subsystem, so to maximize efficiency in mass and power.
- Methods for providing complete autonomous operation - deployment, operational state configuration, position determination, downlink transmission, and reconfiguration to accommodate changes in performance.
- Inter-satellite communications techniques for a constellation of satellites. The communications protocol must handle unique challenges of multiple path artifacts, such as duplicate messages and stale messages. Inter-constellation communications will be used to alert other elements of the constellation of significant events, to

coordinate the operations of the constellation (e.g., station keeping) and to relay data from elements of the constellation to the ground.
- Innovative data management and visualization techniques to handle data from dozens or hundreds of identical spacecraft. The data includes the downlink data, and also other data associated with the operation - data bases of command and telemetry parameters, tracking data, flight software loads, command loads, and acquisition data. This data must be managed and presented to operators in a manner that prevents confusion.
- Lightweight, efficient solar array panels that minimize the effective array mounting area required.
- Lightweight, high output battery cells which can be space qualified.
- Lightweight yet strong composite structural materials that may also: provide thermal control, serve as an effective electronics ground plane, and provide some radiation shielding for electronics.
- Low cost manufacturing techniques that satisfy the cost goal stated above.

23.02 Deep Space Microspacecraft Subsystems
Lead Center: JPL

The strategic plan within the Office of Space Science at NASA calls forintense exploration of a wide variety of bodies in the Solar System within a modest budget. To achieve this will require revolutionary advances over the capabilities of traditional spacecraft systems and a broadening of the toolset through the introduction of new kinds of space exploration systems. Microspacecraft systems (as small as ~10kg, ~10W, or less) of all varieties will enable new missions that are currently impractical. These systems will include, but are not limited to, orbiters, landers, atmospheric probes, rovers, penetrators, aerobots (balloons), planetary aircraft, subsurface vehicles (ice/soil), and submarines. Also of interest are delivery of distributed sensor systems consisting of networks of tiny (<<1 kg) individual elements which combine sensors, control, and communications in highly integrated packages, and which are scattered over planetary surfaces, atmospheres, oceans, or subsurfaces. New technology is needed in all spacecraft subsystem areas, as well as new areas to address this diverse set of needs.

Applicable technology areas include, but are not limited to:
- Miniaturization and/or power reduction in all spacecraft subsystem areas with application in a variety of harsh environments (temperature, radiation, mechanical shock, etc.).
- Avionics, including highly integrated "systems on a chip".
- Propulsion, including chemical and other techniques, also including techniques for machining / manufacturing ultra small parts, and materials joining technologies for microtubes and mini/micro components.
- Power Generation and Management, including isotope power, and solar power, and miniature power electronics.
- Energy Storage, including primary and secondary batteries, fuel cells, and other approaches.
- Thermal Management, including active and passive techniques.
- Integration of functions such as engineering sensors and science instruments, structure, thermal, cabling, propulsion, etc.
- Advances in atmospheric entry systems including ultra-lightweight (a few percent of entry mass) aeroshell technologies, and lightweight pressure vessels which support external pressures of 100+ bars in harsh environments (chemical, radiation, temperature, etc.).

- Advances in techniques and devices for relay communications through atmospheres, ice layers, soil, and oceans.
- Methods and devices for orientation knowledge, navigation, locomotion, autonomy, and control of microspacecraft systems in/on planetary atmospheres, surfaces, subsurface, and submarine environments.

24 Intelligent Systems

The development of Intelligent Systems technologies addresses key strategic technical challenges facing NASA, including the reduction of mission costs, the continuing return of high quality science data through constrained communications bandwidths, and the launching of a new era of exploration, characterized by a sustained presence and in-depth scientific studies. Automated reasoning for autonomous systems will be applied to both the engineering and science elements of exploration missions to provide a more robust closed-loop spacecraft capability. Human-centered computing concepts will be used to optimize the performance of human-machine systems during all aspects of the design, development, and operational phases of these missions. Data management techniques will be applied across the spectrum, from understanding and mining NASA's huge data sets to directing data acquisition intelligently at the remote platforms and instruments.

24.01 Automated Reasoning for Autonomous Systems
Lead Center: ARC

NASA is planning to fill space with robotic explorers, carrying our intelligence and our curiosity, to explore the universe beyond in ways never before possible. To survive decades of operation, these remote agents need to be smart, adaptable, curious, wary, and self-reliant in harsh and unpredictable environments. NASA is soliciting research in automated reasoning for autonomous systems that will enable the design, construction and operation of a new generation of remote agents that perform progressively more exploration at much lower cost than traditional approaches. To achieve ambitious exploration goals, researchers must develop autonomous control kernels that can be commanded by simple, high-level, goal-directed behaviors, such as "make an attitude determination followed by a course correction". These mechanical explorers will be programmable through compositional, commonsense models of hardware and operations behavior. This model-based programming paradigm will allow control systems of spacecraft to be plugged together like lego blocks from libraries of existing models, and will permit novel behaviors to be programmed in a simple intuitive manner. Using these models onboard, the automaton will close the loop on sensor information at the goal level, using advanced deductive planning and execution, scheduling, diagnosis and recovery capabilities to ensure that goals are being met. This goal-directed, model-based programming paradigm is already beginning to emerge through systems like the Deep Space One Remote Agent Architecture.

Achieving capable intelligent robotic explorers will also require systems that learn from their interactions with their environment and adapt in real-time, by using model-based deductive methods to help coordinate and direct collections of biologically-inspired adaptive methods. Remote agents will need to be curious and wary, requiring capabilities for taking action to gain information, assessing risk, planning contingencies and preparing backup resources, or redirecting plans to reduce risk. Finally, these automaton will often act as teams, requiring significant distributed coordination and collaboration capabilities. Specific areas of interest for automated reasoning include the following:

Remote Agent Architectures
- Architectures for onboard operation that support goal-directed commanding, model-based programming, and the plug and play of automated reasoning components.
- End to end architectures that provide a seamless coupling of automated reasoning capabilities for flight and ground operations, and that support easy migration from ground to flight.
- Single and multi-agent architectures that allow the level of autonomy to be easily, precisely and dynamically adjusted.
- Architectures that use automated reasoning to coordinate intelligent design synthesis and science opportunity analysis.

Planning, Scheduling, and Resource Management
- Planning and scheduling systems that use component-based models to support plan generation and dynamic replanning concurrent with execution.
- Advanced planning and scheduling systems that support any-time generation of flexible plans, goal-prioritization, resource optimization, contingency, and sensor-based, iterative and adaptive planning.
- Centralized and decentralized methods for generating plans by coordinating a heterogenous set of special purpose planners.

Executives
- Goal-directed systems for plan and command sequence execution.
- Procedural executives with services for configuration management, resource management and plan running.
- Model-based executives that perform significant deduction within the reactive control loop, and hybrid procedural/deductive executives.
- Distributed, multi-agent execution capabilities.

Fault Protection and Model-based Reasoning Systems
- Model-based and statistical methods for monitoring, command confirmation, fault isolation, and diagnosis from sensor information.
- Model-based reasoning and planning methods for robust recovery & repair, including establishment of a safe operating state as a minimal goal, and preservation procedures from models.

Reasoning Kernels
- Algorithms for high performance deduction and search in real-time, including any-time, systematic and stochastic search algorithms and incremental truth maintenance systems.
- Methods for efficiently abstracting, approximating and compiling models.
- Decision theoretic and adaptive reasoning kernels.

Large-scale, Declarative Modeling and Software Engineering Environments
- Unified languages for model-based programming and declarative specification of software and hardware behaviors.
- Collaborative environments for large scale model building, specification and reuse. Methods that operate on these declarative models/specifications include document generators, visual debugging environments and automated modeling algorithms.
- Advanced techniques for process support, requirements engineering and reverse engineering.
- Methods for code synthesis and controller generation from declarative specifications and models.
- Tools for automatically generating high fidelity, fault injection from component-based models.
- Automated generation of test sequences from component models, and analytic verification methods, including model checking and theorem proving.
- Methods for modeling, code synthesis, simulation, testing and validation, as above, that operate from hybrid discrete/continuous models.

24.02 Human Centered Computing
Lead Center: ARC

Human-centered computing, an approach to the design and implementation of computer systems, seeks to integrate computational systems with human performance and capabilities, such that the total system amplifies, corrects, and leverages the capabilities of both people and machines. Aerospace missions, including the human exploration of space, combine a high degree of automation with often unique system complexity and substantial risk to human lives. The design of computer systems necessarily must take into account not only how people will "interface" with the systems, but fundamental aspects of human perceptual-motor coordination, cognitive operations, and group dynamics. Human-centered computing focuses on the "delta" that respects the particular contributions of humans and machines, designs machines and operational procedures to complement each other, and exploits the understanding of the differences between people and machines to build more capable computer systems. To advance along these lines, proposals are sought in the following areas:
- Advanced AI systems/architectures for mixed-initiative system planning, monitoring, and control, with provision for crew oversight. Architectures that have predictable behaviors, leave people in control, and expose their workings in ways comprehensible to people with different skills.
- "Cognitive prostheses" that qualitatively change the capabilities of human perception, pattern analysis, scientific domain modeling, reasoning, and collaborative activity. Such tools could incorporate any of a variety of modeling techniques such as knowledge-based systems and neural networks, and fit tool operations to ongoing human physical interaction, judgment, and collaborative activity.

- Information technology enabling comprehensive sharing of project-related information and data, which supports intelligent organization, access, and presentation of the information. Particularly, tools that fit the human activities of scientific inquiry and engineering design, and relate the contributions of individuals to the developing plans and products of teams.
- "Knowledge management" tools that relate technical models of human knowledge to: a) nonverbal concepts and perceptual skills, b) the daily activities of workers, including especially how databases are actually used in practice, c) informal on-the-job learning, and d) the career trajectories of novices, experts, and retiring employees.
- Agent-based tools for information gathering, reminding, and alerting; job performance aids that provide cognitive assistance in the context of the daily activities and interests of operations personnel and crew.
- Communication technologies and software tools that enable mission control teams to work together when they are located at different sites and working on several projects.
- Tools for software requirements analysis that incorporate and relate models of databases, legacy systems, and work practices.
- Workflow systems that allow teams of users to formalize and routinely reconfigure their own document templates, processing categories, operating procedures, and archival records.
- Software systems that provide specialized support for collaborative science and engineering tasks, including design, data collection, experimentation, analysis, and model construction to enable scientists and engineers to collaborate as part of distributed project teams at physically separate sites.
- Computing architectures that address the limitations of knowledge-based systems and neural networks, relative to human capabilities, advancing the state-of-the-art in automated perceptual categorization, non-verbal conceptualization, and coordination across multiple sensory modalities. Applications might include planetary probes and rovers with new kinds of instrumentation, signal processing, and sensing-through-movement.
- Visualization tools combining "virtual reality" projection with actual objects in the environment, conveying information about object identity, part relationships, and assembly or operational procedures.

24.03 Data Analysis and Visualization
Lead Center: GSFC

All NASA projects will face the daunting prospect of having to deal with databases of unprecedented size and complexity. We must develop techniques for electronic documentation, electronic process control, massive distributed databases, intelligent archiving and retrieval, and data analysis and visualization. NASA is soliciting technologies to perform a wide range of functions including:

- Automatic data calibration and validation.
- Data viewing and real-time data browse.
- Automated planning of image product generation.
- Natural language interfaces for user to develop high-level queries.
- Analyze historical and/or online ESE sensor data to detect anomalies, identify unexpected values or trends, and detect and classify events automatically.
- Integrate several types of modeling algorithms and directly interface with both UNIX and Windows NT relational database management systems.
- Rapidly implement the resulting modeling in an online application from within the data modeling environment.
- Automated, computationally efficient procedures for rendering from CAD/CAM files.
- Representation and manipulation of multidimensional and hyperspectral data.
- Automatic image data retrieval based on content.
- Softbots and agent-based problem solvers to provide answers to high level inquiries.
- Use of sonification in scientific data analysis.
- Automation of project process information storage and retrieval.
- Image data mining -- tools to provide rapid access to objects of interest within image databases, query by content, example, or sketch, user interfaces to support query specification and refinement, database strategies.
- Trainable object recognition.

- "Intelligent" (goal-directed) data acquisition and/or compression.
- Active vision.
- Parallel processing and real-time vision/recognition.
- Integration of information from multiple sources such as independent databases and real-time sensors.
- Content-based queries of large, geographically distributed collections of images (e.g., as found on the Internet).
- Automatic image registration and change detection.
- Automatically analyze historical and/or online ESE sensor data to detect anomalies, identify unexpected values or trends, and detect and classify events.
- The environment must integrate several types of modeling algorithms and directly interface with both UNIX and Window NT relational database management systems.
- An additional key requirement is to be able to rapidly implement the resulting modeling in an online application from within the data modeling environment.

24.04 Data Understanding and Adaptive Methods
Lead Center: JPL

NASA now collects terabyte-scale datasets routinely from its missions, and charges the scientific community with extracting usable and scientifically relevant information from them. These datasets may be planetary or stellar images, multispectral images, or field and particle event-lists. They may also be engineering time series about spacecraft health collected from on-board sensors. In addition to the ongoing challenges entailed by handling, analyzing and mining very large data sets in archives, NASA now also needs a new framework for performing science data evaluation onboard spacecraft. The future NASA mission set will feature smaller and more numerous spacecraft in an environment of highly constrained uplink and downlink communications, requiring substantial onboard intelligent computation to achieve its goals. New onboard science capabilities will enable mission activities to be directed by scientists without the assistance of a ground sequencing team, robust capture and redirection in making discoveries at the target body, accommodation of the realities of constrained communication links, and the continued return of quality science products from missions.

Through onboard decision-making, scientist-trained recognizers, and judicious use of knowledge discovery methods, a portion of the scientist's awareness can be projected to the space platform, providing the basis for scientist-directed downlink prioritization and the processing of raw instrument data into science information products. This software-based partnership between scientist and space platform can evolve during the mission as the scientist becomes increasingly comfortable with the direct relationship with the space platform, intermediate scientific results emerge, and scientist-directed software updates are uploaded. This subtopic enlists help in developing a new generation of tools and algorithms for effective acquisition and analysis of data and image sets, appropriate for ground or onboard use. Of special interest are: (1) the ability to deal quantitatively with uncertainty present in data, perhaps in a statistical framework; (2) development of flexible models through which observables are linked to quantities of scientific or engineering interest; (3) harnessing database technology for organizing the observed data, models, and inferred knowledge, perhaps in onboard archives, and (4) system concepts for handling interactions between onboard science analysis and event detection capabilities and other functions of an autonomous spacecraft. One or more of these areas should be addressed by every proposal. Specific technical topics of interest include:

- Automated classification of data.
- Supervised and unsupervised learning methods.
- Knowledge discovery techniques.
- Image analysis and segmentation.
- Statistical pattern recognition.
- Time-series feature extraction and analysis.
- Trainable object recognition.
- Automatic image registration and change detection.
- Spatiotemporal data mining.

- Automated planning of image and data product generation.
- "Intelligent" (goal-directed) data acquisition and/or compression.
- Science data analysis algorithms designed for scalable computing.
- System concepts for onboard science.

25 Telerobotics

NASA seeks innovations in the field of telerobotics that will improve remotely controlled robotic operations capabilities for future planetary exploration and Space Station missions. Space telerobotics technology requirements include teleoperated and automated control of non-repetitive tasks, sometimes with significant time delay between operator control and manipulator action. Flexible manipulators will perform complex tasks in a dynamic space environment using novel locomotion, and having the ability to recover from unplanned events.One goal is that by the year 2004, 50 percent of the EVA-required operations on orbit may be conducted telerobotically. Specific areas where innovation is sought include long term survivability of robotic systems, machine intelligence (sensing, perception, planning, and reasoning), sub-surface exploration, robotic dexterity, and navigation capabilities of on-orbit and planetary systems.

25.01 Robotic Systems Including Perception, Planning, and Analysis
Lead Center: JPL

Innovative technologies are sought to support robotic exploration of solar system bodies by intelligent, low power, and low weight robotic systems. Advanced mobility and manipulation systems are needed as well as their on-board and ground-based sensing, perception, planning and reasoning systems.

- Microrover (less than 30kg) and nanorover (less than 1kg) related technologies are needed to support planetary surface exploration over rugged terrain. Surface mobility concepts under consideration include walking machines, wheeled rovers, unique suspension systems, hybrid locomotion, and hopping/jumping machines.
- Technologies are needed to support exploration in shallow and deep locations below the surface and underwater.
- Aerobot technologies will support exploration in the atmospheres of Venus, Mars, Titan and the outer planets including high (740 K) and/or low (75 to 200 K) temperatures and extreme pressures (100 bars). Technologies include: gondola instrument pointing and attitude control to optimize stereo imaging for 3D surface reconstruction and analysis; on-board perception for relative and absolute position determination; and altitude control, lateral mobility, and path planning techniques and systems.
- Technologies for manipulation from rovers, landers and underwater vehicles are needed.
- Component mechanism technologies to support planetary robots are needed, such as low-mass high-torque actuators, collapsible wheels and structures, legs, and lightweight manipulators and masts.
- Miniature sensors are needed such as stereo cameras, Sun-based location sensors, and integrated multi-functional sampling mechanisms.
- Earth-based perception, planning, and analysis technologies are needed to enable distributed planning of resource constrained missions. Scene analysis will assist in localization, task selection, and path planning. Internet-based stereo visualization will enhance scientific understanding of the scene.
- On-board perception and planning technologies are needed including science data analysis, target selection, near and distance feature identification, visual servoing of instruments to targets, path planning, autonomous navigation, multi-sensor fusion, and fault detection and recovery.

Sensing and perception and planning to provide both the capability to function under a variety of conditions without human intervention and provide a means for efficient interaction with the human when needed. These approaches may include capabilities for:

- Situation assessment, response planning and associated sensing and environmental modeling;

- Natural language understanding and language planning as a modality for efficient interaction;
- Plan representation which integrates functionally with language understanding and planning to support instrutability;
- Improved safety and reliability of plans and plan execution based on innovative architectures, sensing methods, plan representation techniques, etc.;
- Support of simultaneous deliberative planning and safe real time action, including reaction to insure safety.

Operation of the ISS will require the ability to view the outside of the station from user selected viewpoints as required by a variety of external maintenance jobs. Since locations at which cameras can be mounted on station are limited, a flying camera controlled by the crew is of particular interest. One of the enabling technologies for such a camera is a light weight, low power sensor/system that provides relative navigation with respect to the station without requiring the addition of external markers, antennas or other extensive exterior modifications.

- Optical Correlation pattern recognition, particularly in hardware implementation and algorithm development.

25.02 Telerobotic Servicing
Lead Center: JSC

Proposals are solicited for innovative concepts which will increase the capabilities for robotic systems to perform servicing of space systems while minimizing the workload to EVA and IVA astronauts, and ground operators. Technologies that will improve worksite efficiency with tools and fastening systems, expand the range of servicing tasks beyond box ORU replacement, improve operator efficiency with advanced displays and control systems, and offload on-orbit servicing to ground based operators are sought. Specific technology requirements include the following:

- Ground-based control technology for space-based robots which is able to compensate for time delays of several seconds without move and wait strategies.
- Ground-based real-time simulations that contain methods for calibrating and synchronizing with space-based robotic worksites through video or other sensor information.
- Supervised and traded control systems which allow for seamless human interaction. The ability to accommodate both planned and unplanned human and autonomous operations within a task are essential.
- Space system maintenance planning tools, and individual ORU maintenance task planning and execution tools.
- Target and non-target based identification and acquisition of ORUs. Ability to operate robustly in the adverse lighting conditions of space is essential.
- Tools and fastening systems that accommodate both EVA astronauts and servicing robots well and improve the time to remove and replace ORUs. Smart sensor-guided tools that provide higher precision or lower contact forces are one potential approach toward this objective.
- An electrically operated robotic arm suitable for handling moderately heavy payloads from a mobile vehicle in a hazardous environment. Unit should be suitable for use in a Class One, Division One, Group A environment.

25.03 Tele-Operations/Virtual Environment
Lead Center: ARC

Innovative hardware and software are needed for using virtual environments techniques and technologies to enhance teleoperations applications. Teleoperations, in this context, includes telerobotics, telescience, telepresence, and distributed, collaborative virtual environments. Application areas include flight and ground operations development, analyses, training, and support. Areas in which innovation are solicited include the following:

- Internet-based interactive command generation and display technologies for distributed collaborative on-orbit and planetary robotics applications. Examples include integrated voice, videoconferencing, planning tools and visualization, stereo visualization, and mission simulation and Internet securuty.

- Immersive multi user and collaborative virtual environments that include high fidelity visual image generation and haptic feedback. Haptic feedback includes physics based systems capable of simulating dynamic six degree of freedom force and motion interactions based on inertial properties.
- Body ported telescience operational support systems for stand-alone and collaborative in situ activities.
- Functionality would include multimedia procedural and reference support; two way data, video, and audio communications; and efficient user interfaces that facilitate intensive manual activities.
- Cost effective payload training systems in standalone and distributed, collaborative virtual environments for both individual payloads and multiple payloads integrated into a space station environment. These systems would include remote interaction with high fidelity hardware/software simulators. Focus areas include cognitive operational and science discipline training as well as gross and fine motor manipulative skills training

26 Communications

All NASA missions rely on telecommunications for their successful completion. NASA develops innovative communications technologies for its own use and collaborates with US industry in the development of commercial technologies that have the potential to satisfy NASA system needs. To fulfill these goals, NASA conducts a program of research and technology at the device, subsystem and system level in such areas as microwave, millimeter wave, and optical communications; digital processing, modulation, and coding; communications architectures, networks, and system protocols.

26.01 RF and Optical Communications for Deep Space Missions
Lead Center: JPL

NASA's goals for future interplanetary missions require advances in higher-capability, smaller, and more power-efficient spaceborne telecommunications. Due to the enormous distances from Earth, design of these systems imposes unique challenges for transmitter sources with higher effective isotropic radiated power (EIRP) and higher receiver sensitivities, while maintaining low power consumption and low system mass. Technology options being considered include improved radio frequency and optical communication systems. Additionally, sensors being planned for future Earth-orbital missions will produce significantly higher data rates as well. For these missions, the limitations on communications come not from physics, but from limits on RF spectrum allocation. To circumvent this limitation, NASA is developing high-data-rate laser communication systems. Data rates up to several Gbps can be transmitted from Earth-orbit-to-ground, or via space-space relay.

Areas in RF communications where innovations are sought include:

- Modulation and coding techniques and network designs for deep-space communications that reduce cost, spacecraft power and mass, bandwidth and operations requirements.
- Ultra-small, low-cost, low-power, deep-space transponders and components. Including low-voltage and high-efficiency integrated circuits such as microwave monolithic integrated circuits (MMICs) and MMIC filters. Signal-processing circuits for receivers that provide carrier tracking, command and ranging capabilities. Low-voltage, multi-function MMIC designs with integrated filters to provide low-noise down-conversion, automatic gain-control, up-conversion, and transceiver functions at Ka-band (32 GHz). MMIC modulators to provide large linear phase modulation (above 2.5 radians), high-data rate BPSK/QPSK modulation at Ka-band. Miniature, ultra-stable oscillators for deep space communications and GPS applications. Miniature, low-loss X-band (8.4 GHz) and Ka-band switches and diplexers.
- Low-mass, high-gain, high-efficiency antennas typically with diameters less that 2 meters, integral with spacecraft surfaces, or that can be reliably stowed in low volumes.
- Photonic technologies that permit new and more efficient ways to implement RF communications and phased-array systems including components and techniques applicable to i) optical-RF signal distribution systems, ii) optically controlled transmit-receive modules, iii) optical beam-forming networks, iv) optical samplers, modulators, detectors, mixers and RF-locked semiconductor lasers.

Also of interest to the RF communications system development is:

- Miniature, high-efficiency power amplifiers and RF power devices operating in the X- or Ka-band, transmitters with output power levels ranging from 3 watts to 20 watts, and both innovative solid-state as well as thermionic devices that can survive the space environment with mean-time-to-failure of ten years or more. MMICs supporting miniature, high-efficiency power amplifiers at Ka-band (primary focus) and X-band (secondary focus) such as gain blocks, multi-bit digital phase shifters and power cells. Support elements like low-loss, miniaturized isolators, high-efficiency integrated DC-DC power converters, and miniaturized power dividers and combiners. Advanced packaging concepts and techniques for the packaging and miniaturization of high-efficiency power amplifiers at X- and Ka-band.

For optical communication systems, innovative concepts are solicited for space-based applications in the following areas:

- Ultra-lightweight, baffled, thermally stable diffraction-limited telescopes.
- Efficient, space-qualifiable, lightweight diode and diode-pumped lasers and/or laser driver-modulators.
- High-speed (equal to or greater than 1.0 GHz) modulators for diode-lasers with more than 200 milliwatts of output power.
- Acquisition, tracking, and pointing techniques that reduce mass, power and complexity.
- Focal-plane-array detectors with built-in (on-chip) processing and/or focal plane arrays combining redundant CCD and QAPD sensors.
- High-speed, high quantum-efficiency, very low noise FPA's (eg. CCD, APS, CID) with large field of view (5 mrad) and small pixel sizes (eg. CCD, APS, CID) with large field of view (> 5 mrad) and small pixel sizes (< 20 micron).

Also interested in infra-red (1 - 2 micron) FPAs:

- Lightweight, low-power, two-axis, mechanical and non-mechanical beam steering devices with steering ranges greater than 1 degree.
- Optical phase-control devices.
- Narrow-band (0.1 Angstrom), high-throughput (more than 0.60) optical filters.
- Lightweight stray-light control concepts.
- Power-efficient modulation and coding systems.

Also of interest for optical free-space communication are technologies to enable low-cost ground reception systems including:

- Low-cost optical telescopes (photon-buckets) from 3 to 10 meters in diameter.
- Low-cost 1-m diameter optical telescopes that can accurately track Earth-orbiting satellites.
- Ultra-narrow-band (0.01 to 0.5 Angstrom) optical filters.
- Adaptive-optics systems to mitigate the effects of atmospheric turbulence.
- Innovative concepts for low-cost telescope mounts and enclosures.
- High-efficiency, high-speed, optical detectors and detector amplifiers. Also highly efficient, integrated detector amplifiers with bandwidths greater than 1 GHz and large optical signal collection diameters.
- Clock and data signal recovery assemblies with 20 dB input signal dynamic range and update dates of 1 kHz.

26.02 RF and Optical Communications for Earth Satellites
Lead Center: LeRC

Innovations are sought for application to commercial satellite communications and NASA missions. Advanced techniques and products (radio frequency and optical) are invited that support commercial low, medium, and geostationary Earth orbiting (LEO, MEO, GEO) satellite networks for integrated, fixed, transportable, and mobile broadcast and/or wireless communications and information services. Innovations are expected to offer significant improvements in performance, weight, power efficiency, reliability and/or cost. Products are sought in the following areas:

- Software/hardware technologies to enhance Internet applications, videoconference, multimedia and video distribution techniques and applications over satellite networks. Innovative approaches to software simulation tools for rain fade compensation and for evaluating the effects of mutual interference between space and terrestrial wireless systems.
- Wide scan angle (+/- 60 deg), low profile, transmit/receive Ka-band antennas, Ku/Ka band transceivers and closed-loop acquisition/tracking algorithms for aeronautical communication satellites.
- Vacuum and solid-state electronics amplifiers with improved performance at frequencies up to 100 GHz including ancillary technologies such as electron emission, computer-aided design and electronic materials and device characterization that are required in the development of microwave power modules, vacuum microelectronic devices, traveling wave tubes and MMICs
- RF components and sub-systems based on Si and SiGe or novel materials such as ferroelectrics, diamond films and high-temperature superconducting films or utilizing microfabrication techniques
- Bandwidth and power efficient single or multi-channel digital modems; aggregate rates from 100 Mbps to 1.2 Gbps; single chip or chip set integration; and novel robust coding schemes for high performance data links and next generation data on demand systems.
- Innovative application of critical on-board satellite signal processing, switching and routing functions for 100 fold increase in capacity with no increase in mass and power.
- Latency-tolerant data communication protocols and enhanced Asynchronous Transfer Mode (ATM) and related network technologies for interoperable space-terrestrial networks. Data protocols for LEO/MEO networks.
- Low cost, Ka-band flat plate array antennas, 2 watt Ka-band, MMIC power amplifiers and low noise block down-converters for USAT applications. Low cost, precision tracking Ka-band earth terminals for high data rate (OC-3 to OC-12) direct to-Earth downlinks from LEO/MEO spacecraft.
- Novel system designs and advanced optical technologies are needed to enable efficient ultra high data rate communications on space-to-space, space-to-ground, and/or ground-to-space links for GEO or non-GEO satellite networks. Areas of interest include lightweight, low cost and thermally stable telescopes; efficient, high power (1 W) semiconductor diode lasers and arrays; high bandwidth modulators and detectors; techniques to mitigate the effects of atmospheric attenuation/turbulence and methods to reduce mass, power and complexity of the acquisition/tracking/pointing process.
- Software/hardware technologies to enhance configuration management, performance monitoring, fault isolation, and security of data communications networks involving satellite links integrated with terrestrial networks.
- Low cost, hand-held transceivers/display units capable of receiving only, transmitting only, and both receiving and transmitting satellite-relayed disaster-related warning or mitigation information broadcast over special frequencies allocated for emergency and weather use.
- Very low weight, high data rate, mobile communications and data compression technologies suitable for use in conjunction with remote sensing instruments placed in Unmanned Aerial Vehicles (UAVs) and supporting real-time transmission of video and multi-spectral images back to science investigators.

27 Instrument Optics Technologies

The continued need to reduce cost and improve performance of future scientific payloads involving optical instrumentation requires innovations in optical component design, materials, fabrication techniques, metrology and control technologies encompassing the electromagnetic spectrum from the gamma-ray region through the infrared. These innovations are needed in support of future astronomy, astrophysics, planetary and earth-observing missions which must be downsized in mass, volume and cost while achieving significant improvement in performance.

27.01 Optical Materials, Fabrication Techniques and Metrology
Lead Center: MSFC

Novel optical materials, specialized optical fabrication techniques, and new optical metrology instruments and components for earth and space based applications are needed, as follows:

- Develop novel materials and fabrication techniques for producing ultra-lightweight mirrors, high-performance diamond turned optics, and ultra-smooth (2-3 angstrom rms) replicated optics that are both rigid and lightweight. Lightweight silicon carbide optics and structures are also desired.
- Develop optics for focusing EUV and x-ray radiation, where reductions in fabrication time and cost are sought. Developments are also needed in the areas of surface roughness and figure characterization of EUV and curved x-ray optics, especially Wolter systems.
- Develop novel materials and fabrication techniques for producing cryogenic optics. Testing techniques, including both full- and sub- aperture testing, for cryogenic optics are needed. Also desired are techniques for testing the durability of and stress in coatings used in harsh environments, particularly cryogenic optics.
- Develop novel techniques for producing and measuring coatings and polarization control elements. Optical coatings for use in the EUV, UV, visible, IR and far IR for filters, beamsplitters, polarizers, and reflectors will be considered. Broadband polarizing- and non-polarizing cube-type beamsplitters are also needed.
- Perform development related to fabrication of x-ray, gamma-ray, and neutron collimators that have the precision necessary to achieve arcsecond or sub-arcsecond imaging in solar physics and astrophysics when used in stationary multi-grid arrays or as rotating modulation.
- Develop portable and miniaturized state-of-the-art optical characterization instrumentation and rapid, large-area surface-roughness characterization techniques are needed. Also, develop calibrated processes for determination of surface roughness using replicas made from the actual surface. Traceable surface roughness standards suitable for calibrating profilometers over sub-micron to millimeter wavelength ranges are needed.
- Develop instruments capable of rapidly determining the approximate surface roughness of an optical surface, allowing modification of process parameters to improve finish, without the need to remove the optic from the polishing machine. Techniques for testing the figure of large, convex aspheric surfaces to fractional wave tolerances in the visible are needed.
- Develop efficient, analytical, optical modeling and analysis programs capable of determining the ground-based and space-based performance of complex aberrated optical telescopes and instrument systems will be considered. Also, simple, well documented, flexible programs which generate commands to operate a numerically controlled polishing machine, given the tool wear profile and surface error map are desired.
- Develop very low scattered light optical material thin film mirror coatings or mirrors for broad-band white light applications to planet detection space telescopes.

27.02 Light Control, Lasers and, Other Precision Sources
Lead Center: GSFC

Lasers and electro-optic devices are required for Earth and Space Science instruments. We are seeking for the following devices:

- High power (> 5W) fiber optic amplifers for use with single frequency or very narrow band spectroscopic sources in the 800-860 nm and 930 - 950 nm wavelength ranges.
- High power (> 5W) semiconductor optical amplifers for use with single frequency or very narrow band spectroscopic sources in the 800-860 nm and 930-950 nm wavelength ranges.
- Tunable narrow band optical filters compatible with semiconductor and Nd host based lasers.
- Tunable atomic vapor absoprtion filters compatible with semiconductor and Nd host based lasers.
- Electrically efficient (> 5%) ultraviolet lasers in the 300-350 nm wavelength range.
- Efficient (> 5%) tunable single frequency high power (> 100 mW) fiber optic lasers.
- Efficient (> 30%) frequency doubling devices for low power (diode) lasers.
- Techniques for producing smooth diamond mirrors and membranes for x-ray and IR beamsplitters and windows. For UV/IR systems:
  - desire a free-standing diameter of 2 inches or greater.
  - desire 1/2 to 1/4 fringe at HeNe (0.63 um) for operation longward of absorption (> 6 microns wavelength).

  - desire 1/40 fringe at HeNe for operation from UV to mm.
- Narrow-bandwidth acousto-optic tunable filters that can be tuned across large wavelength regions (> 2 octaves) from the visible through the infrared (0.4 to 5.0 microns).
- Continuous-wave high-resolution (narrow-line) infrared solid-state lasers that are tunable from 1.0 to 5.0 microns.

27.03 Diffractive Optics: Design and Fabrication Techniques
Lead Center: MSFC

New and innovative design tools, techniques and fabrication methods are needed to fully exploit the inherent possibilities of diffractive optics to reduce size weight and costs in optical systems and components. Areas of interest include:

- Generalized design software for kinoform diffractive optical elements with applications toward direct write electron beam-lithography, or photo-lithography fabrication techniques.
- Design and modeling methodologies software for multilevel sub-wavelength structures.
- New low-cost fabrication methods for producing diffractive optic elements.
- High aspect ratio structures electron beam lithography fabrication techniques.
- Metrology techniques for high aspect ratio (3:1) sub-micron structures.
- Large aperture, with sub-micron feature size, diffractive optic fabrication techniques.
- Innovations are sought in using analog spatial light modulators (SLMs) as diffractive optical elements for the control of light. Application areas in which analog devices and methods might be applied include spot generation for directing light waves to disparate destinations, active optics for dynamic correction of environmentally induced aberrations, spatial (rather than angular) addressing of optical memory, and compact and simple display of dynamic image information.
- Large area (2cm squared) blazed diffractive optical element deposited on a curved surface with optical power for remote sensing computed-tomography imaging spectrometers in the visible and infrared.
- Design and fabrication of diffractive optics for multi-wavelength operation. These could be elements that are useful for wavelength demultiplexing of white light passively illuminated scenes and/or for specialized spectrometry applications.
- Diffractive optics for use in compact, lightweight instrumentation.

27.04 Optics Technologies for Space and Earth Observing Systems
Lead Center: GSFC

The continued need to reduce cost and improve performance of future scientific payloads involving optics requires innovations in optical component technologies encompassing the electromagnetic spectrum from the gamma-ray through the infrared. These innovations are to support new astronomy, astrophysics, planetary- and Earth-observing experiments, which must be miniaturized while compensating improvements in capabilities. Aspects of instrument development that can benefit from new technology cover the spectrum from optical system design and modeling, through optical materials and thin-film coatings and their characterization, to wavefront sensing and component and subsystem testing. These need to be applied to integrated optical system components such as spectrometers, hyperspectral systems, and diffractive elements.

- Improved optical techniques for image-motion compensation and image quality.
- Fiber-optic routing of signals for communications, control, and metrology of optical instruments.
- Use of small fiber bundles for sampling small fields of view and integral-field spectroscopy.
- Novel techniques for producing high-performance, low-scatter, optical materials and coatings for use from soft X-ray through far IR in reflector, filter, polarizer, and beamsplitter applications.
- Techniques for producing and mapping low-scatter, defect-free coatings for the EUV and soft x-ray regions.
- High-accuracy measurements of refractive index at cryogenic temperatures.

- Thin foil filters and proportional counter windows and high-throughput, rugged support meshes for the x-ray and EUV regions.
- High-performance, diamond-turned optics and lightweight silicon carbide optics and structures are desired.
- Techniques for producing smooth diamond membranes for X-ray and IR window applications.
- Thin film technology for the soft X-ray through EUV spectral regions, including advances in high-throughput, low-scatter, defect-free coatings, and defect-mapping methodology, particularly for mirrors in the 13-nm region.
- State-of-the-art optical characterization instrumentation for miniaturized components.
- Novel optical system design and analysis software, particularly with regard to factoring in as-manufactured performance and programmatic parameters.

28 Interdisciplinary Technologies in Astrobiology

Astrobiology is the study of the living universe. It provides a scientific foundation for multidisciplinary studies of (1) the orgin and distribution of life in the universe, (2) an understanding of the role of gravity in living systems and (3) the study of the Earth's atmospheres and ecosystems.

28.01 Technologies for Understanding the Origin, Evolution and Distribution of Life in the Universe
Lead Center: ARC

Astrobiology studies on the emergence of living systems from molecular chaos require technologies to search for extant or extinct life, to obtain an organic history of planetaries bodies, to explore water sources, and to distinguish microorganisms and biologically important molecular structures within complex chemical mixtures. The search for life on other planetary bodies will also require systems capable of moving and deploying instruments across and through varied terrain to access biologically important environments.

NASA seeks innovations in the following technology areas:

Mobility Systems:
- Innovative techniques that meet these needs are required, e.g., for Mars, technologies that would enable or enhance the performance of long distance ground roving, tunneling, or flight vehicles and for Europa, technologies to enable the penetration of ice. Desirable features include the ability to carry an array of instruments and imaging systems, to provide an aseptic operation mode, and to maintain a pristine research environment.
- Low cost light weight systems to assist in the selection and acquistion of the most scientifically interesting samples are also of significant interest.

Analytical Tools:
- High sensitivity (femtomole or better), high resolution methods applicable to all biologically relevant classes of compounds for separation of complex mixtures into individual components.
- High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodied within individual compounds and structures.
- High spatial resolution (5 angstrom level) electron microscopy techniques to establish details of external morphology, internal structure, elemental composition and mineralogical composition of potential biogenic structures.
- Development of modern, innovative computer software to support astrobiological studies of the origin and evolution of life. The areas of special interest are (1) biomolecular and cellular simulations, (2) evolutionary and phylogenetic algorithms and interfaces, (3) DNA computation, and (4) image reconstruction and enhancement for remote sensing.
- Nondestructive structural characterization of micro-areas or microsamples of rocks and minerals by diffraction (1-100 micron scale of observation).

28.02 Technologies for Understanding the Evolution of Biological Systems in Space
Lead Center: ARC

An essential element of Astrobiology is understanding the evolutionary development of biological processes leading from single cell organisms to multicellular specimens and to complex ecological systems over multiple generations. Throughout its evolution, life on Earth has been exposed to the constant force of gravity. Therefore, it is axiomatic that gravity helped shape and continues to influence the structure, function, and ongoing evolution of all living organisms. Because of its pervasive influence, understanding the effects of gravity on the evolution of living systems is a fundamental question of substantial, inherent scientific value in our quest to understand life. In addition, radiation of varying levels is assumed to have varying effects on the development and evolution of life. Currently, man-tended microgravity flights, e.g., Shuttle, Mir, International Space Station, provide excellent opportunities to study the effects of both varying gravity levels and radiation on life, and numerous Space Life Science facilities have been developed to utilize these platforms. With the omnipresent nonpathogenic organisms currently found on board spacecraft, the effects of varying radiation exposure on biofilms and general microbial mutation in spacecraft and habitat interiors may provide an example for study opportunities aboard current Shuttle launches. Knowledge of the effects of radiation and gravity on lower organisms, plants, humans, and other animals, as well as elucidation of the basic mechanisms by which these effects occur, will be of direct benefit to the quality of life on Earth through applications in medicine, agriculture, industrial biotechnology, environmental management, and other activities dependent on understanding biological processes over multiple generations.

In support of the above areas of investigation, technologies must be developed in the following categories:

- Biotechnology: determining mutation rates and genetic stability in a variety of organisms as well as accurately determining protein regulation changes in microgravity and radiation environments.
- Automated chemical analytical instrumentation for determining gross metabolic characteristics of individual organisms and ecologies, as well as chemical composition of environments.
- Imaging technology with high resolution and low power requirements.
- Habitat support: technologies for supporting miniature ecosystems, isolated from their support environments, and transmitting data collected with the automated chemical analytical instrumentation described above. Candidate technologies include sensor and telemetry systems as well as variable-spectrum, low power light sources for simulating conditions on the early earth.
- Algorithms for processing and analyzing recovered data.

These technologies must be miniaturized to minimize weight, volume and power requirements and must operate autonomously for extended periods of time to accommodate monitoring multiple generations of organisms. Thus, instrumentation must be self-calibrating, require no or minimal consumables and be remotely commanded.

28.03 Technologies for Understanding the Evolution of the Earth's Atmosphere and Ecosystem
Lead Center: ARC

Astrobiology includes the study of evolution, which is essentially the study of ecological processes through time. Astrobiology intersects with NASA's Earth Science (ES) through the highly accelerated rate of change in Earth's biosphere being brought about by human actions. One particular area of study applicable to astrobiology with direct links to ES is microbe-environment interactions. These interactions can be seen in carbon cycles and nitrogen cycles. Some examples of rapid changes that affect these microbial processes are increases in UV, increases in average and seasonal temperatures, and changes in the length of the growing season-all of which are key issues in both ES and astrobiology. This research requires unique instrumentation and information science technologies that are not covered in the ES program, including:

- Miniature to microscopic, high resolution, field worthy, smart sensors or instrumentation for the accurate and unattended monitoring of environmental parameters that include but are not limited to, solar radiation (190-800 nm at < 1nm resolution), ions and gases of the various oxidation states of carbon and nitrogen (at the nanomolar level for ions in solution and at the femtomolar or better level for gases), in a variety of habitats (e.g., marine, freshwater, acid/alkaline hot springs, Antarctic climates or boreholes into the Earth).
- High resolution, high sensitivity (femtomolar or better) methods for the isolation and characterization of nucleic acids (DNA/RNA) from a variety of organic and inorganic matrices.

- Mathematical models capable of predicting the combined effects of elevated pCO_2 (change in Co2 over the eons) and solar UV radiation on carbon sequestration and N_2O emissions from experimental data obtained from field and laboratory studies of C-cycling rates, N-cycling rates, as well as diurnal and seasonal changes in solar UV.
- Microscope DASI (Digital Array Scanning Interferometer) or its equivalent to study soil cores, microbial communities, pollen samples, etc., in a laboratory environment for the detailed spectrscopic analysis relevent to evolution as a function of climate changes.

9.0 Submission Forms and Certifications

NASA SBIR 98-1 SOLICITATION

FORM 9A - PROPOSAL COVER

	Subtopic Number	Last 4 digits of Firm's Phone #	Change Letter	
PROPOSAL NUMBER	**98-1** _ _ . _ _	_ _ _ _	_	**(Instructions on Reverse Side)**

SUBTOPIC TITLE ____________________

PROJECT TITLE ____________________

FIRM NAME ____________________

MAIL ADDRESS ____________________

CITY/STATE/ZIP ____________________

PHONE ____________________ FAX ____________________

CEO E-MAIL ____________________ PI E-MAIL ____________________

PHASE I AMOUNT REQUESTED: $_______ DURATION: ______ MONTHS

OFFEROR CERTIFIES THAT:

As defined in Section 2 of the Solicitation, this firm qualifies as a:	YES	NO
(a) Small business concern	☐	☐
(b) Socially and economically disadvantaged small business concern	☐	☐
(c) Women-owned small business	☐	☐
The requirements described in Section 3.0 are met:		
(d) Limits on subcontracting and consultants	☐	☐
(e) Eligibility of the Principal Investigator	☐	☐
(f) Prior federal funding	☐	☐
(g) Proposals to other agencies	☐	☐
(h) Subcontracts and agreements	☐	☐
(i) Government Furnished Equipment	☐	☐
No substantially duplicative proposal is submitted to more than one subtopic.	☐	☐

ENDORSEMENTS: Principal Investigator: Corporate/Business Official:

Typed Name ____________________

Title ____________________

Signature ____________________

Date ____________________

PROPRIETARY NOTICE (If Applicable, See Sections 5.4.1 & 5.5)

NOTICE: For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to this proposer as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement. This restriction does not limit the Government's right to use Information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages __________ of this proposal.

PROPOSAL COVER INSTRUCTIONS

General--Complete Form 9A and sign it in ink. This original cover sheet shall be submitted with the original paper copy of the proposal. Make photocopies to use as the cover sheet for other copies of your proposal and submit an extra copy separately. (See Sections 3.2, 3.3, 3.4 and 6.1 for further instructions)

1. Proposal Number--This number does not change even if the firm gets a new phone number. Complete the proposal number as follows:

   a. Enter the four-digit subtopic number.
   b. Enter the last four digits of your firm's telephone number.
   c. If you are submitting different proposals under the same subtopic, enter a change letter as appropriate to differentiate proposal numbers.

   Example I: A company with telephone number 273-8126 submits one proposal to subtopic 06.03. The proposal number is 06.03-8126.

   Example II: A company with telephone number 392-4826 submits three different proposals to subtopic 11.03. The proposal numbers are: 11.03-4826, 11.03-4826A, and 11.03-4826B

2. Subtopic Title: Enter the title of the subtopic that this proposal will address. Use abbreviations as needed.

3. Project Title: Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title. Avoid words like "development" and "study".

4. Firm Name: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

5. | | |
   |---|---|
   | Address: | Enter address where mail is received. |
   | State: | Enter 2-letter designation (example Maine: ME) |
   | Zip Code: | Enter 5- or 9-digit code |
   | Phone: | Enter general phone and Fax number of the firm. |
   | CEO E-Mail: | Enter e-mail address for Business Official |
   | PI E-MAIL: | Enter e-mail address for Principal Investigator |

6. Phase I: Amount Requested: Enter proposal amount from Budget Summary. The amount requested should not exceed $70,000. Round to nearest dollar. Do not enter cents. Duration: Enter the proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss the reason in the text of the proposal.

7. Certifications: The offeror must respond to the following certifications cited briefly on the proposal cover. Put a check in the appropriate boxes.

7(a), (b), (c). See definitions in Section 2 of this solicitation

7(d). Limits on subcontracting and consultants. By answering yes, the offeror certifies that a minimum of two-thirds of the research and/or analytical effort for the proposed project will be performed by the small business concern, as described in Section 3.5.1, Part 9.

7(e). Eligibility of the Principal Investigator. By answering yes, the offeror certifies that the proposed principal investigator meets all the requirements described in Section 1.4.3 and, if the PI is currently the employee of an academic or a non-profit research organization, a copy of the release letter from that organization is also included.

CONTINUED

7(f). Prior federal funding. By answering yes, the offeror certifies that they have received federal funds for substantially similar work and these projects are described in Part 11 of the proposal. By answering no, the offeror certifies that no such funds have been received.

7(g). Proposals to other agencies. By answering yes, the offeror certifies that they have submitted or plan to submit proposals of similar content to another federal agency and that these proposals are described in Part 11 of the proposal. By answering no, the offeror certifies that no such proposals are presently under consideration or will be submitted this year.

7(h). Subcontracts and agreements. By answering yes, the offeror indicates that a copy of any subcontracting or consulting agreements described in Part 9 of the proposal is included as required in Section 3.5. If such agreements are lengthy, the signature page should be included. These copies may be submitted in a reduced size.

7(i). Government Furnished Equipment. By answering yes, the offeror certifies that unique, one-of-a-kind Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities and that appropriate authorizations have been obtained (see Section 3.5.1 Part 8, Section 4.2.2 Part 7, and Section 5.1.4). By answering no, the offeror certifies that no Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities.

8 No substantially duplicative proposal is submitted to more than one subtopic. By answering yes, the offeror certifies that only one proposal for substantially the same activity has been submitted within this Solicitation.

9. Endorsements: The proposal should be signed by the proposed Principal Investigator and an official of the firm qualified to make a contractual commitment on behalf of the firm. The PI and the Corporate Official may be the same person. The copy of the cover sheet submitted as the single original should have original signatures.

SBIR 98-1 SOLICITATION

FORM 9B - PROJECT SUMMARY

		Subtopic Number	Last 4 digits of Firm's Phone #	Change Letter	
PROPOSAL NUMBER	**98-1**	_ _ . _ _	_ _ _ _	__	**(Instructions on Reverse Side)**

PROJECT TITLE

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS

NAME AND ADDRESS OF PRINCIPAL INVESTIGATOR (Name, Organization Name, Mail Address, City/State/Zip)

NAME AND ADDRESS OF OFFEROR (Firm Name, Mail Address, City/State/Zip)

PROPOSAL PAGE 2

INSTRUCTIONS FOR PROJECT SUMMARY

1. **Proposal Number**: (See instruction for Form 9A, Cover Sheet).

2. **Project Title**: Enter the same title as shown on your Proposal Cover.

3. **Technical Abstract**: Provide a summary of 200 words or less of your proposed project. The abstract must not contain proprietary information and must describe the proposed innovation. (See Section 3.4.2. for how it addresses the stated subtopic requirement, the project objectives, the effort proposed, the results anticipated, and the expected NASA applications and benefits)

4. **Potential Commercial Applications**: Summarize the direct or indirect commercial potential of the project, assuming the goals of the proposed research or R&D are achieved.

5. **Name and Address of Principal Investigator**: Enter name, organization name and mailing address as shown in the Proposal Cover sheet.

6. **Name and Address of Offeror**: Enter firm name and mailing address as shown on the Proposal Cover sheet.

SBIR 98-1 SOLICITATION

FORM 9C - SBIR PROPOSAL SUMMARY BUDGET

FIRM: PROPOSAL NUMBER:

DIRECT LABOR:

Category	Hours	Rate	Cost
			$

TOTAL DIRECT LABOR:
(1) $ ____________

OVERHEAD RATE % of Total Direct Labor

OVERHEAD COST:
(2) $ ____________

OTHER DIRECT COSTS:

Category	Cost
	$

TOTAL OTHER DIRECT COSTS:
(3) $ ____________

(1)+(2)+(3)=(4) SUBTOTAL:
(4) $ ____________

G&A RATE ______% of Subtotal G&A COSTS:
(5) $ ____________

(4)+(5)=(6) TOTAL COSTS
(6) $ ____________

ADD PROFIT or SUBTRACT COST SHARING PROFIT/COST SHARING:
(7) $ ____________

(6)+(7)=(8) AMOUNT REQUESTED:
(8) $ ____________

This proposal is submitted in response to NASA SBIR Program Solicitation 98-1 and reflects our best estimates as of this date:

NAME AND TITLE (Typed): SIGNATURE:

DATE:

INSTRUCTIONS FOR SBIR SUMMARY BUDGET

By using this form, the offeror submits to the Government a pricing proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting system (See Section 3.6 for further information). This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, on a budget explanation page immediately following the budget in the proposal. (See below for discussion on various categories)

(1) **Direct Labor**--Enter labor categories (e.g., principal investigator, laboratory assistant, administrative staff), hourly rates of pay and the hours for each labor category.

(2) **Overhead**--Specify current rate(s) and base(s). The offeror may use whatever number and types of overhead rates that are in accordance with the firm's accounting system and approved by the cognizant federal negotiating agency, if available. If no rate(s) has (have) been negotiated, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I that will be subject to approval by NASA. Multiply Direct Labor by the Overhead Rate to determine the Overhead Cost.

(3) **Other Direct Costs**

a. Materials and Supplies: Indicate types required and estimate costs.

b. Documentation Costs or Page Charges: Estimate cost of preparing and publishing project results.

c. Subcontracts: Include a completed budget--including hours and rates--and justify details. (See Sections 3.5, Part 9 and 5.12 for further information)

d. Consultant Services: Indicate name, daily compensation, and estimated days of service. (See Section 3.5, Part 9 for further information.)

e. Computer Services: Computer equipment leasing is included here.

List all other direct costs that are not otherwise included in the categories described above.

(4) **General and Administrative (G&A)**--Specify current rate and base. Use current rate negotiated with the cognizant federal negotiating agency, if available. If no rate has been negotiated, a reasonable indirect cost (G&A) rate may be requested for Phase I, subject to approval by NASA. Multiply (4) Total Direct Cost by the G&A Rate to determine G&A Cost.

(5) **Profit or Cost Sharing**--See Sections 3.6.4, 5.8, and 5.9.

(6) **Amount Requested**--This should exclude any cost-sharing and not exceed $70,000.

For assistance in completing your proposal, use this checklist to ensure your submission is complete.

CHECK LIST

1. General

1.1 The offeror has read all instructions in this Solicitation and understands that proposals not meeting all requirements may be non-responsive and may not be evaluated.
1.2 The offeror understands that proposals must be received by NASA no later than by 5:00 p.m. EDT on July 7, 1998. (Section 6.4.3).
1.3 Postal Submission includes the original signed proposal plus three copies. (Section 6.4).
1.4 The entire proposal (including any supplemental material) shall not exceed a total of 25 8.5 x 11 inch pages (Section 6.4).
1.5 The entire proposal must be submitted in the order outlined below. (Section 3.1).

2. Cover Form 9A

2.1 The proposal and innovation is submitted for one topic only. (Section 3.4).
2.2 Certifications in Form 9A are completed. (Section 3.4.1, 3.6.1)
2.3 The period of technical performance does not exceed six months and the funding request does not exceed $70,000. (Section 5.1).
2.4 Form 9A submitted via Internet (Section 6.3).
2.5 Printed Version of Form 9A is signed (Section 6.4) and included in Postal Submission.

3. Summary Form 9B

3.1 Form 9B submitted via Internet (Section 6.3).
3.2 Printed Version of Form 9B (Section 6.4) is included in Postal Submission.

4. Technical Proposal

4.1 The proposed innovation is described in the first paragraph of the Technical Proposal (Section 3.5).
4.2 The technical proposal contains all twelve parts in order. (Section 3.5).
4.3 Phase-II objectives are discussed (Section 3.5).
4.4 Commercial applications potential is discussed. (Section 3.5).
4.5 Any pages containing proprietary information are labeled "Confidential Proprietary Material" and kept to the minimum essential for the proposal. (Section 3.5).
4.6 The Electronic Technical Proposal was:
4.6.1 submitted over the Internet, (Section 6.3) OR
4.6.2 placed on an electronic media and included with the Postal Submission Package. (Section 6.4).

5. Budget Form 9C

5.1 Form 9C submitted via Internet (Section 6.3).
5.2 Printed Version of Form 9C is signed (Section 6.4) and included in Postal Submission.